The Structured Uses of Concepts as Tools

Comparing fMRI Experiments that Investigate either Mental Imagery or Hallucinations

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Abstract

Sensations can occur in the absence of perception and yet be experienced 'as if' seen, heard, tasted, or otherwise perceived. Two concepts used to investigate types of these sensory-like mental phenomena (SLMP) are mental imagery and hallucinations. Mental imagery is used as a concept for investigating those SLMP that *merely resemble* perception in some way. Meanwhile, the concept of hallucinations is used to investigate those SLMP that are, in some sense, *compellingly like* perception.

This may be a difference of degree. Attempts to reliably differentiate between instances of each type of SLMP remain unresolved. Despite this, the *concepts* of mental imagery and hallucinations are each routinely used independently of the other. These uses are especially interesting in those published accounts of experiments where equivalent findings about the neuroanatomical correlates of SLMP are reported in support of diverging knowledge-claims about the role of SLMP in neurocognitive processes. This practice presents a puzzle. To examine one aspect of this puzzle, I compare the uses of these two scientific concepts in three ways: examining their roles in differentiating between types of SLMP; exploring how their respective historical developments intersect; and analysing their contributions in neuroimaging experiments.

In presenting this series of comparative analyses, I will draw on three themes from historical, philosophical, and social studies of scientific practices: interest in material contributions to knowledge; accounts of how concepts are used in experiments; and explorations of the historical conditions within which current practices emerge. Building on this literature, my comparative analyses supports five related claims.

My first claim is that the concepts of mental imagery and hallucinations are each used as independent tools in neuroimaging experiments. My second claim is that, as experimental

tools, the concepts of mental imagery and hallucinations are each *used for* investigating discrete epistemic goals. My third claim is that there are implicit interdependent associations that *structure* the uses of these two concepts as tools for independently investigating these discrete epistemic goals in neuroimaging experiments. This third claim rests on my analyses of both past and present uses of each concept. Firstly, as seen in their intersecting histories, there are disciplined performances of using the concepts of mental imagery and hallucinations that carry-along shared associations about the mediating role of SLMP in thought. Secondly, these interdependent 'mediator-view' associations continue to structure the independent uses of each concept as a tool for investigating SLMP in pursuit of specific goals. Taking this further, my fourth claim is that recognising the *structured uses* of the concepts of mental imagery and hallucinations can help to account for how equivalent SLMP-neuro-correlates are generated in support of diverging knowledge-claims. Finally, my fifth claim is that the structured uses of these concepts as tools can contribute to experiments in ways analogous to, yet not equivalent with, the *active contributions* of material instruments.

Bringing these claims together, I argue that the concepts of mental imagery and hallucinations operate as structured tools that can actively contribute to the knowledge generated by neuroimaging experiments. In presenting this argument I seek to demonstrate that examining the *structured uses of concepts as tools* can complement existing approaches to studying how the heterogeneous dynamics of experimental practices can come to contribute to scientific knowledge in unintended ways.

Declaration

This is to certify that:

i. the thesis comprises only my original work towards the PhD

ii. due acknowledgement has been made in the text to all other material used; and

iii. the thesis is fewer than 100,000 words in length, exclusive of tables, maps, bibliographies, and appendices.

Signed, Eden Tariq Smith, 18 September 2018

Preface

This following is my own work. None of the chapters are published, or in the process of publication. At the time of submission, the only related publication is drawn from just one of the five claims developed further here in Chapter Eight; a claim supported by research detailed more extensively here in chapters Chapter Two, Three, and Four:

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The research for this thesis was undertaken during my PhD candidature, and has been funded through an Australian Government Research Training Program Scholarship (*Australian Postgraduate Award*, *2014 Round 1)*. In addition to this, I received faculty and school grants that allowed me to travel to international conferences and receive feedback from acclaimed scholars in my field. I am also grateful to academics in the History and Philosophy of Science program who provided teaching and research assistant opportunities throughout my candidature. In relation to this, I would also like to recognise the support shown by professional staff – notably, Sarah Gloger and June McBeth – who went beyond their expected roles in helping me find accessibility solutions. Finally, I wish to acknowledge the history of colonial practices I am a product of. While far from adequate, I offer my respects to the Wurundjeri people on whose land I lived and worked while conducting this research.

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I also want to take this opportunity to publicly recognise the wide range of support I relied upon to reach this once-inconceivable milestone, and in maintaining an interest in what adventures might follow. Specific thanks are also due: to my parent Gray, for teaching me to question everything; to Fi, for celebrating divergent thinking; to Althea and Brooke, for continuing conversations after our contexts diverged; to Jo, for cultivating my interest in public policy; to Glen, for recognising the beauty of being in the moment and sharing that with me; to Mich, for teaching me to ask for more than I thought possible, and for steadfastly expecting to share whatever the future brings; to Tamlyn, for sharing intentions and enthusiastically investing in me time and time again; to Hän, for teaching me to hope, and repeatedly re-committing to the new puzzles of shared futures; to Wens, for effortless-connections regardless of how time passes; to Nicole, for adapting to my particularities; to Sony, for never taking me too seriously; to Max, for meeting me wherever I am; to Bek, for being such a resilient force of delightful whimsy periodically lighting up my solar system; to Kate, for generously sharing struggles and solidarity; to Frances, for co-creating a space of trust within which we can live alongside each other, regardless of what else may change; to Christopher, for expressing joy in momentary connections of mutual recognition; to Cam, for the unexpected chance to discover our uncanny similarities and valuable differences; to Anna, for demonstrating the power of defying norms, and sharing the challenges and value of resilience; to Naomi, for constantly questioning assumptions; to Bonnie, for such inspiringly nerdy excitement about brains; to Craig, for timely distractions and orbiting in ways that so reliably return to the spaces we create together; to maia, for thinking out-loud and letting me listen; to L, for helping to reframe uncertainties as possibilities; and to Tracey, for helping to build a future where dyslexia is no obstacle to academia – or anything else.

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Introduction

A passing familiarity with experiences of either mental imagery or hallucinations may suggest that these are quite different.[1] I will return to these differences in a moment. First, I want to focus on the uses of *mental imagery* and *hallucinations* as scientific concepts for investigating specific types of sensory-like mental phenomena – hereafter, SLMP.[2] As an analytic category, *SLMP* include any sensations experienced in the absence of relevant perceptual stimuli. Reported in all modalities, sensory-likeness is often described as an experience that is, to varying degrees, 'as if' seen, heard, tasted, or otherwise felt.

As a scientific concept, mental imagery is used to investigate those SLMP that *resemble* perception. Meanwhile, the concept of hallucinations is used for investigating those SLMP *compellingly* like perception. Debates over why some SLMP merely resemble perception while others have this compelling sense of perception remain unresolved. Attempts to explain this distinction frequently boil down to an inverse set of contrasting typical *characteristics* (see Table 1). However, as detailed in Chapter Three, none of the typical characteristics in either set reliably align with only those experiences of SLMP that either resemble perception or are compelling enough to be mistaken for perception.[3]

This raises numerous questions about the continued reliance on these inverse characteristics for individuating typical instances of mental imagery or hallucinations. I do not intend to address most of these. For example, I leave aside ongoing debates about

[1] See Appendix 1 (Annotated Glossary) for additional clarification on the various domain-specific and disputed terms/phrases included throughout this thesis (with italised links included for some key terms).

[2] See Chapters One and Two for my approach to studying *scientific concepts*, and Chapter Three for a detail on mental imagery and hallucinations as types of SLMP.

[3] Note that I will only be focusing on conscious endogenous experiences of SLMP that occur in the waking state; thus, I exclude SLMP experiences that are induced and/or part of altered-states of consciousness.

whether mental imagery and hallucinations are discursive propositions that (fail to) *refer* to mutually-exclusive types of SLMP. Whatever the outcome of such debates, these concepts are used in experiments regardless of these broader questions of reference. As such, I will focus on a different question: what lessons emerge from comparing how the concepts of mental imagery and hallucinations are each *used* for investigating specific types of SLMP?

In this context, I will treat scientific concepts as fragmentary *bodies of knowledge* that emerged as temporarily stable tools for isolating instances of specific types of phenomena for further investigation.[4] When it comes to using mental imagery and hallucinations as scientific concepts in neuroimaging experiments, each function independently of the other to *individuate* a discrete type of SLMP for further investigation. Mental imagery is the dominant concept used in experiments investigating neurocognitive functions thought to involve *ordinary* SLMP. Meanwhile, hallucinations feature as the key concept in experiments that investigate those neurocognitive dysfunctions thought to involve *abnormal* SLMP. In each case, neuroimaging techniques are used to find correlations between experiences of SLMP and localised changes in *neural activity* within anatomically-bound regions of interest (hereafter, I will call these findings *SLMP-neuroanatomical-correlates)*.

Comparing publications from experiments that include these techniques highlights that the same SLMP-neuroanatomical-correlates are reported regardless of whether the concept of mental imagery or hallucinations was used to individuate the SLMP of interest. This overlap is to be expected.[5] More puzzling is that the potential relevance of these overlapping findings goes unrecognised in published accounts of individual experiments. In such cases, equivalent SLMP-neuroanatomical-correlates are taken as evidence for conflicting

[4] Also see Chapters One, Two, and the *scientific concepts* entry in Appendix 1 (Annotated Glossary).

[5] Similar comparisons have been reported before (Allen et al. 2008; Hill and Linden 2013, 34–35).

knowledge-claims; claims that diverge depending on the concept used to investigate the SLMP.[6]

To investigate this puzzle, I draw together diverse literature on three themes that have emerged within historical, philosophical, and social studies of scientific practices: an emphasis on material contributions to knowledge; the uses of concepts in experiments; and the historical conditions within which current practices emerge. Focusing on these themes, I seek to develop a convergence between strands of research that concentrate on either material or conceptual elements of *scientific practice*. In the next section I will introduce these areas of scholarship and how I intend to build upon them. Then, to conclude this introduction, I will outline how these three themes will be drawn together to investigate the ongoing relevance of the historical interdependence of the concepts of mental imagery and hallucinations for their independent uses in neuroimaging experiments.

Studying Scientific Practices

As mentioned, I aim to build on three themes within the broader field of philosophical, historical, and social studies of experimental practices. The first theme emerges from accounts of scientific practice that emphasise the role of materiality in the emergent dynamics of various sciences, technologies, and societies. Of these, I will draw attention to scholarship that positions material-instruments as contributing to scientific knowledge in non-neutral ways. The second theme emerges from scholarship contributing to historical and philosophical studies of the sciences by exploring the conceptual elements of investigative practices. Of these, I will focus on research highlighting that scientific concepts are used as tools that are contributing to experiments in ways that extend beyond their roles in reference

[6] This is one example of the conceptual challenges within neuroimaging experimental practices, for discussion of this broader issue see: (Abend 2016; Bunzl, Hanson, and Poldrack 2010; Lenartowicz et al. 2010; Poldrack and Yarkoni 2016).

and representation. The third theme emerges from a tradition of integrating historical and philosophical studies of the sciences to highlight the importance of examining the contingent conditions current scientific practices emerged within.

As I will argue in Chapter One and Two, these research themes offer compatible insights. While these themes criss-cross historical, philosophical, and social studies of science and technology, specific insights often emerge from different approaches to studying scientific practices. As Joseph Rouse (2011b) notes, the enclaves that form around specialist approaches to studying the sciences can often obscure their over-arching insights. For example, both Science and Technology Studies (*STS*) and History and Philosophy of Science (*HPS*) are overlapping amalgamations with contested boundaries, yet each field generates distinctive insights from their specialised approaches to studying scientific practices. Therefore, rather than attempt to either clarify or dissolve these contested boundaries, I aim to highlight an underappreciated convergence between the insights emerging within scholarship that contributes primarily to STS or HPS respectively.

As a research field, STS is a federation of diverse approaches that emphasise the importance of social studies for understanding the interactions between science, technology, and society (B. R. Martin, Nightingale, and Yegros-Yegros 2012). Within this context, historical and sociological approaches have often been combined to offer insights relevant for current practices; while the relationship between philosophical and sociological approaches have been much more turbulent (Giere 1987; Roosth and Silbey 2009). Despite this uneasy relationship, philosophical examinations of those insights drawn from historical and social studies of science and technology have also been cultivated – particularly, within the strand of STS that examines dynamic technoscientific practices (Ihde and Selinger 2003).

Studies of the materiality of technoscientific practice have often explored the role of *nonhumans* in the generation of scientific knowledge.[7] Within this context, the notion of material *agency* has developed to describe the non-intentional actions through which the forces of material entities interact with other entities to produce effects on the world. This notion of *agency* should be understood as a situated process of emergent relational actions that need not be intentional (Knappett and Malafouris 2008). Questions about how materials *act* can be seen in explorations of how material nonhumans – such as mechanical instruments and laboratory animals – contribute in unintended ways to the practices that generate, mobilise, and stabilise knowledge-claims (e.g., Haraway 2006; Hacking 1983; Ihde 1979; Latour 2005; Robins 2008; Stengers 1997).

In contrast to the enthusiastic interdisciplinarity of STS, the field of HPS often operates as a self-conscious link between discrete historical or philosophical studies of the sciences (Ellis et al. 2014; Giere 2012; Schickore 2011). However, within both historical and philosophical approaches there has been increasing interest in the materiality of scientific practice. This is especially prominent in scholarship where philosophical questions about experimental practices are considered of equal value to those about scientific theory (e.g., Hacking 1988; Steinle 2002). Likewise, historical research has similarly emerged around the objects of scientific enquiry and the material-technologies used to investigate them (e.g., Burian 1997; U. Klein 2001; Rheinberger 1993, 2000a). As these examples highlight, HPS has increasingly provided a space for integrating historical and philosophical studies of scientific practices (Chang 2012a; Steinle and Burian 2002). It is within this integrated-HPS

[7] While the value of the term 'nonhuman' remains contested (Casper Brunn Jensen 2003a, 88; Stengers 2010), it provides a well-known short-hand for including the wide range of heterogeneous actants that have been described as collaborating with humans in the performative construction of scientific knowledge.

literature that scholars have returned to examining the conceptual elements of scientific experiments.

Positioned in these ways, the fields of STS and HPS can each be understood as approaching the study of scientific practices from different perspectives: with STS approaches focusing more on describing how current scientific practices include dynamic relationships between social and material elements; while HPS approaches focus on either the material or conceptual elements that have contributed to past scientific practices. Based on the view that these different perspectives are valuable, I seek to draw on the converging insights that bridge STS and HPS (rather than attempt to integrate the fields themselves).

The foundations for these bridges can be found in the overlapping contributions to the long-running trend towards studying scientific *practices* within both STS and HPS (Soler et al. 2014, 3).[8] As part of this trend, some philosophically-oriented approaches engage with literature from within both STS and HPS. For example, Ian Hacking (1995a, 8) introduced a collection of historical and philosophical essays on scientific practice by noting that some contributors, such as Pickering, Peter Galison and Yves Gingras, "made a reputation for themselves with their historico-sociological studies of big science". Furthermore, even when contribution to the fields of STS and HPS are not crossing these permeable boarders, they often explore complementary themes (Rouse 2011b). For example, Theodore Arabatzis and Jutta Schickore (2012, 399) note that the historical depth within integrated HPS complement the insights into the intricacies of current sciences offered by STS.

While there are other options, I will concentrate on exploring how Pickering's analogy between *conceptual structures* and material instruments offers one way of bridging STS accounts

[8] For some other examples, see collections that bring together philosophical, historical, and sociological approaches to studying scientific practice (Daston 2000b; Hacking 1995a; Ihde and Selinger 2003).

of non-human agency and HPS accounts of *conceptual practices*. To this end, I will position Pickering's analogy in relation to insights offered within these largely distant approaches (in Chapters One and Two). Firstly, I will demonstrate that Pickering's view of scientific knowledge is shared by a range of scholars contributing to both STS and HPS. In brief, my interpretation of the shared component of these diverse views is that scientific knowledge provides accounts of reality (as it exists independently of human access to it) that are simultaneously objective (in the sense that they can be robust and intersubjective) and contingent (that is, situated within the conditions of its generation).[9]

Then, narrowing my focus to STS accounts of material nonhumans, I will provide a quick tour through some insights offered in the work of Haraway, Bruno Latour, Don Ihde, and Andrew Pickering – focusing on how each offers philosophical explorations into the non-neutral ways that material nonhumans participate in the production of technoscientific knowledge (Casper Brunn Jensen 2003b, 229–30; Selinger 2003, 11). I will then provide an equally selective overview of recent HPS accounts of how concept-use can contribute to experimental practices in ways that extend beyond their representational roles. Within this increasingly diverse area of integrated HPS research, I will focus on accounts of stable scientific concepts being used in investigative practices: uses that are theory polyvalent (e.g., Arabatzis 2012; Arabatzis and Nersessian 2015); extend beyond mere mental and linguistic representations (e.g., Nersessian 2012, 246; MacLeod 2012, 50); and operate as tools for structuring multiple aspects of experimental practice (e.g., Boon 2012, 220; U. Feest 2010, 2012; Steinle 2012, 106). Along the way, I will also weave in some insights drawn from the longer tradition of investigating the relevance of the historical development of concepts for understanding their currently stable uses – drawing most heavily on interpretations of

[9] For some historical context for the changing ideals associated with scientific objectivity, see (Daston and Galison 2007).

scholarship by Gaston Bachelard and Georges Canguilhem (e.g., Canguilhem 1994; Cutting 1987; Rheinberger 2009; Tiles 1984).

With this context in place, I will then present my understanding of Pickering's notion of conceptual structures. In doing so, I seek to highlight a convergence between accounts of the unexpected and non-neutral contributions of material and conceptual elements of scientific practices respectively. Developing this convergence helps to connect three broader themes within historical, philosophical, and social studies of scientific practices: the material contributions to knowledge; the uses of concepts in experiments; and the historical conditions within which current practices emerge. Building on these themes, I will introduce two connected possibilities: that the uses of scientific concepts as experimental tools are structured for the pursuit of specific goals; and that these *structured uses* of scientific concepts contribute to experimentally generated knowledge in an analogous way to the active contributions of material instruments.

Using the Concepts of Mental Imagery and Hallucinations in Experiments

To explore these possibilities, I offer a series of comparative analyses of two scientific concepts – mental imagery and hallucinations – that focuses on examining if and how the uses of these concepts are structured as tools for investigating specific types of SLMP. As detailed in Chapter One and Two, the delineation of a given type of phenomena (e.g., SLMP that resemble perception) from other types of phenomena (e.g., SLMP with a compelling sense of perception) involves condensing and integrating an available body of relevant knowledge. This process requires articulating causally-fundamental characteristics of the phenomena into operational definitions of concepts that can individuate instances of the phenomena of interest for the purpose of investigating it directly (Bloch 2012a, 192, 215; U. Feest 2010, 173). Therefore, in Chapter Three I introduce how mental imagery and hallucinations are currently used to conceptualise different experiences as discrete types of SLMP.

Following this, I will ask how the concepts of mental imagery and hallucinations are differentiated from each other (and other types of SLMP) for use as independent tools in neuroimaging experiments. To answer this, I examine the central distinguishing characteristics that are implicit within, or appended to, the definitions of mental imagery and hallucinations respectively. These characteristics will be shown to operate as proxy criteria for individuating specific types of SLMP in ways appropriate for investigating functional and dysfunctional neurocognitive processes respectively.

Based on this examination, I then present two inter-related claims regarding the uses of the concepts of mental imagery and hallucinations for individuating discrete types of SLMP experiences. Firstly, I describe the inverse set of characteristics that justify differentiating between those SLMP conceptualised as either mental imagery or hallucinations. Secondly, I demonstrate that these typical characteristics no longer provide this justification: offering only an ambiguous delineation between the uses of these two concepts in practice; and completely failing to reliably distinguish between functional and dysfunctional SLMP as these are experienced. Bringing these two claims together, I argue that there is an unresolved tension carried-along by using the concepts of mental imagery and hallucinations for delineating between ordinary and pathological experiences of SLMP.

To explore this tension further, I then look at the independent uses of each concept in experimental practices. As mentioned, the concepts of mental imagery and hallucinations are both used in experiments that identify SLMP-neuroanatomical-correlates; experiments that seek to explain the role of SLMP in functional or dysfunctional neurocognitive processes respectively. For example, the concept of mental imagery is used in experiments that investigate the localised changes in neural activity that correlate with of experiences of SLMP that resemble perception. Meanwhile, the concept of hallucinations is used in experiments that investigate localised changes in neural activity that correlate with experiences of SLMP that, having a compelling sense of perception, are considered symptomatic of disordered neurocognition.

It is these experimentally identified SLMP-neuroanatomical-correlates that contribute to neurophysiological explanations for experiences of SLMP as either a functional process of neurocognition or dysfunctional processes that disrupt neurocognition.[10] In this way, the concepts of mental imagery and hallucinations are each used as stable concepts: concepts that reliably individuate a type of SLMP for the purposes of investigating the neurophysiological processes underlying that specific experience of SLMP (as it relates to neurocognitive function or dysfunction respectively).[11] However, considering the difficulty of individuating between different types of SLMP detailed in Chapter Three, comparing those neuroimaging experiments that investigate SLMP-neuroanatomical-correlates using the concepts of either mental imagery or hallucinations reveals the puzzle I mentioned earlier.

This puzzle starts with the recognition that neuroimaging experiments frequently report similar SLMP-neuroanatomical-correlates regardless of whether the concept of mental imagery or hallucinations was used to individuate the SLMP in question (Allen et al. 2008; Hill and Linden 2013, 34–35). This overlap is rarely discussed. Even when these similarities are mentioned they tend to be explained away: unique SLMP-neuroanatomical-correlates are expected to be found for both mental imagery and hallucinations. As such, any similarities

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[10] The differences between the *neurocognition* and *neurophysiological processes* are clarified in Appendix 1 (Annotated Glossary).

[11] The ability for concepts to be useful regardless of whether they successfully refer to a natural kind has been established elsewhere (Bloch 2012b; J. McCaffrey and Machery 2012, 270). Note that while mental imagery and hallucinations are used as stable scientific concepts in experimental practices, both remain heavily debated in broader scientific and philosophical discourses. As such, these concepts function on a smaller scale compared to reasoning style level 'organising concepts' such as objectivity and probability (Hacking 2002; Sciortino 2016).

are taken to be merely an overlapping element within larger distinct neurophysiological processes. It is the dissociated elements of such networks that are proposed to underlie the phenomenological differences between mental imagery or hallucinations (e.g., Badcock and Hugdahl 2012b; Grossberg 2002; Shine et al. 2015). Explained in this way, the focus remains on proposing neurophysiological-based explanations that are unique to just one concept of SLMP or the other.

As these explanations suggest, similarities in the SLMP-neurophysiological-correlates reported by experiments using the concept of either mental imagery or hallucinations are not problems in and of themselves. It is quite possible that mental imagery and hallucinations share some SLMP-neuroanatomical-correlates while other SLMP-neuroanatomical-correlates remain unique to one of the other of these types of SLMP.[12] However, agreement as to which SLMP-neuroanatomical-correlates are unique to experiences of mental imagery and which are unique to hallucinations remains elusive. As such, the knowledge context within which neuroimaging experiments are conducted do not provide reliable explanations for the independent uses of the concepts of mental imagery or hallucinations for investigating functional and dysfunctional SLMP respectively.

To understand this tension, it is important to consider the intimate historical contexts within which the current scientific concepts of mental imagery and hallucinations emerged. As Steinle (2002, 410) puts it, historical context is important for examining the types of questions pursued by experiments and how these cohere with specific epistemic situations and experimental activity. Therefore, in Chapter Four I will explore one of the historical conditions that help to explain how – given the reliance on interdependent characterisations

[12] For example, implicating similarly localised activity in the explanatory mechanisms of two distinct mental phenomena may reflect genuine differences (macroanatomical regions are well-known to contribute to multiple neurocognitive function and there can also be multiple networks of activity that incorporate overlapping regions during different mental phenomena).

– the concepts of mental imagery and hallucinations came to be used as independent tools for investigating discrete *epistemic goals* in neuroimaging experiments.[13]

To this end, I provide two narratives drawn from a combination of existing historical accounts and my own analysis of documents from the time-periods of interest. The first of these historical sketches focuses on how the concept of mental imagery came to be used within neuroimaging experiments that investigate functional neurocognition. The second will explore how the concept of hallucinations came to be used within neuroimaging experiments that investigate dysfunctional neurocognition. In presenting these narratives I make no attempt to provide a comprehensive historical account of either of these conceptual developments. Instead, I simply aim to illustrate how the current uses of the concepts of mental imagery and hallucinations can be better understood by appreciating their interlocking histories.

Once positioned within their historical context, the typical inverse characterisations of mental imagery and hallucinations can be understood as explaining differences between desirable and undesirable experiences of SLMP within a knowledge-context inherited from philosophical accounts of SLMP. For example, the relationship between the characteristics that individuate instances of the concepts of mental imagery and hallucinations can be understood as historically contingent associations that emerge from a 'mediator-view' of SLMP. As detailed in Chapter Four, this mediator view was inherited via nineteenth-century empiricist philosophical accounts of SLMP. Furthermore, while the knowledge-context within which these inverse characterisations emerged was later abandoned, these concepts

[13] Note that this approach offers a narrow account of an intersection in the development of two conceptual tools; other historiographical approaches would be able to highlight additional historically contingent conditions and cultural resources these made possible the scientific practices that use these conceptual tools. For more on the value historiographical pluralism, see: (Camilleri 2015).

each continued to carry the mediator-view series of associations into new contexts. Developing these various points, I argue that mediating-role associations about SLMP provided the structure within which the concepts of mental imagery and hallucinations came to be both delineated in relation to each other and to operate independently of each other.

Positioning these historical sketches in relation to the converging insights from studies of scientific practices developed in Chapter Two, the current independent uses of these two concepts can be understood as structured by the shared sets of associations evident within their interdependent histories. Having established their historical interdependence, the previously mentioned overlap in the reported SLMP-neuroanatomical-correlates for mental imagery and hallucination will then be re-examined.

The second half of this thesis will therefore detail a series of comparisons between the roles that the current independent uses of the concepts of mental imagery and hallucinations play in the generation of knowledge about the neurocognitive processes involved in various types of SLMP.[14] To begin, Chapter Five will document the method I developed for systematically sampling a collection of published reports of neuroimaging experiments that investigated SLMP-neuroanatomical-correlates conceptualised as either mental imagery or hallucinations. In brief, in the first stage I follow guidelines for systematically reviewing scientific literature to collect a sample of peer-reviewed publications reporting neuroimaging experiments using the concept of either mental imagery or hallucinations. During this step, I identify two sets of articles for further analysis: one set (Set-M) consists of articles that report on fMRI experiments that investigated the neural mechanisms that underlie mental

[14] This approach seeks to disambiguate specific features of these dynamic practices; it is intended to sit alongside alternative insights drawn out by focusing on different features (such as material, social, and institutional elements) found within neuroimaging practices. To repurpose Janet Vertesi's (2015, 31) insights, these multiple analytic perspectives offers ways to productively "draw and redraw the contours of salient moments in the field".

imagery; the other set (Set-H*)* consists of articles that report on fMRI experiments that investigated the neural mechanism responsible for hallucinatory experiences.[15]

In the second stage I incorporate multiple methodological approaches to identify four article subsets. In each subset articles reported the same brain region of interest (ROI) as implicated in functional magnetic resonance imaging (fMRI) experiments that used either the concept of mental imagery or that of hallucinations. Each of these article subsets provides a paradigmatic example of published fMRI experiments within similar SLMP-neuroanatomical-correlates that use the concepts of either mental imagery or hallucinations. Therefore, in the third methodological step I develop criteria for a qualitative analysis of concepts as used within published accounts of neuroimaging experiments.

This comparison shows that, as expected, similar SLMP-neuroanatomical-correlates are reported regardless of whether the SLMP are conceptualised as mental imagery or hallucinations. More surprisingly, these overlapping findings were never considered to be part of the shared processes underlying all SLMP expected prior to divergence into the discrete processes underlying experiences of either mental imagery or hallucinations. Instead, similar SLMP-neuroanatomical-correlates were always taken as indicative of distinct mechanisms relevant to either functional of dysfunctional neurocognition depending on the concept used for the SLMP investigated.[16]

This comparison therefore offers one way of exploring the puzzle I discussed earlier. In many ways, these overlapping findings reflect the intended uses of these two concepts (as

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[15] An *fMRI (functional magnetic resonance imaging)* is a type of *neuroimaging* technique used in experiments across the *neurosciences* – see Appendix 1 (Annotated Glossary).

[16] There are various concepts of mechanism in biology (D. J. Nicholson 2012) and mechanism-focused experiments are one of a number of approaches to experimentation (Darden 2008, 958–59). For clarification of my focus on *mechanism (explanatory mechanism)* please see Appendix 1 (Annotated Glossary).

reported in the experimental aims).[17] Mental imagery is a concept used for investigating the *functional* role of ordinary SLMP in a range of neurocognitive processes (including, memory, imagination, and language processing). Meanwhile, the concept of hallucinations is used in investigations into the role of SLMP in a range of *dysfunctional* neurocognitive processes (particularly in relation to memory, language, attention, and judgment). However, in each case, the structured uses of these concepts contributed in ways that went beyond these intended uses.

Given this, most of Chapter Six will focus on examining how otherwise similar findings (of SLMP-neuroanatomical-correlates) can contribute to diverging experimental knowledge; a divergence that hinges on whether the SLMP is investigated using the concept of mental imagery or hallucinations. With this established, Chapter Seven will detail some of the ways that the concepts of mental imagery and hallucinations were each used in the experimental designs and methods documented in these two sets of articles. With this analysis, I seek to demonstrate that these two concepts were each used as data-gathering tools that contributed to dynamics of neuroimaging experiments in ways that were structured by their uses for investigating discrete epistemic goal ('making sense of' either functional or dysfunctional experiences of SLMP respectively).

Building on this claim, I argue that there were empirical presuppositions – inherited through those associations sedimented within the paradigmatic characterisations of mental imagery and hallucinations – that structured the ways that these concepts could be used as tools for generating data that aligned with broader epistemic goals. To support this argument, I demonstrate that similar experimental data (that the conceptual tools of mental imagery

[17] Within the context of this thesis I am taking intentions to be those articulated by the aims reported in the published accounts of their experiments (not the individual motivations of the scientists involved).

and hallucinations helped to generate in different experiments) contributed to diverging knowledge-claims depending on the disciplined performances embodied in the structured ways each concept was used independently of the other. Rather than make any normative claims about the value of knowledge generated by these experiments, I will focus on describing the uses of specific concepts to attention to the value of paying attention to the uses of tools in experiments.

Chapter Eight will clarify the coherence between, a) the proposal I introduce in Chapter Two, b) my findings from the examination of the intersecting histories of these concepts in Chapter Four, and c) my analysis of the independent uses of each concept in neuroimaging experiments in Chapter Six and Seven. Drawing these connections together, I will argue that it is through their *structured uses* (as tools for pursuing specific goals through experimental investigation) that the concepts of mental imagery and hallucinations can actively contribute to the knowledge generated in the neuroimaging experiments; contributions that are analogous to, yet not equivalent with, the active contributions of material instruments within experimental practice.

Finally, to conclude, I will review each step in this research project. In doing so, I seek to demonstrate the value of drawing together insights from approaches that focus on either material or conceptual elements of scientific practices. In doing so, I will demonstrate how entrenched associations can be carried along by the structured uses of concepts (as tools for pursuing specific epistemic goals) in ways that can actively contribute to the knowledge generated by neuroimaging experiments. This conclusion will include a brief discussion of two implications emerging from my research that warrant further investigation. My first suggestion is that recognising the unresolved interdependent associations between the independent uses of each concept is relevant to understanding those knowledge-claims generated in neuroimaging experiment that investigate either mental imagery or hallucinations.[18] The second implication emerges from the intersection of my research and existing interdisciplinary discussions about improving experimental neuroimaging practices.[19] However, while gesturing towards this point of intersection, aspirations of further interdisciplinary research are beyond the present scope. Instead, my focus is on developing some converging insights that emerge from accounts that focus on either the material or conceptual elements of scientific practice. In taking this approach, I aim to demonstrate how examining the structured uses of two interdependent scientific concepts – mental imagery and hallucinations – can help to identify how each concept can operate as an independent experimental tool that contributes to experimentally generated scientific knowledge in an analogous way to material tools.

[18] For example, while clinically-focused literature is increasingly engaging with the ambiguous distinctions between ordinary and dysfunctional experiences of experiences of SLMP, this is not reflected in experimental practices.

[19] For example, there are a range of well-recognised yet unresolved methodological and philosophical issues in relation to neuroimaging experiments which will be considered briefly in Chapter Five.

1 Material and Conceptual Contributions to Scientific Practice

Drawing on scholarship within historical, philosophical, and social studies of scientific practice, I aim to highlight a convergence between accounts that focus on either the *material* or *conceptual* contributions to experiments. While interest in the materiality of scientific practices has been growing for decades, attention has only recently returned to examining how scientific concepts contribute to experiments. Within the wealth of scholarship on material practices, I focus on those that examine how non-intentional agency of material instruments can actively contribute to scientific knowledge. Meanwhile, the accounts of conceptual practice that I draw on each explore how the uses of scientific concepts extend beyond their cognitive and linguistic roles in reference and representation.

I will not offer a comprehensive review of the scholarship contributing to these diverse research areas; it would be difficult to do justice to either, let alone both.[20] Instead, I will focus on those aspects that strengthen the existing bridging themes between accounts that focus on either material or conceptual contributions to experiments. These bridging themes are especially prominent in analogies likening the role of conceptual elements in scientific practice, to the active role more frequently attributed to the material elements of experiments. Of these analogies, I will begin with Pickering's description of conceptual structures as acting in emergent and unpredictable in ways that are like those actions attributed to material instruments.

To clarify the context for my approach, I will locate Pickering's work within a range of broadly congruent yet diverse approaches to studying scientific practices. To introduce the first of these approaches, I position Pickering's approach as one of many that contribute to accounts of scientific knowledge as simultaneously objective and contingent. In this context,

[20] In addition, for the sake of brevity, I have relegated definitions and discussion of disciplinary specific terms and phrases to Appendix 1 (Annotated Glossary).

scientific knowledge can be considered objective in the sense that it provides robust and intersubjective descriptions of real objects and phenomena; where the reality of these objects or phenomena is such that they are taken to exist independently of human access. At the same time, scientific knowledge can be considered contingent on the specific conditions within which it was generated – including various material, social, and conceptual elements of scientific practices. To introduce the second approach, my focus narrows to a small selection of accounts describing material instruments as actively contributing to the generation of objective-yet-contingent scientific knowledges. The selection chosen highlights a strand of STS literature that develop nuanced accounts of the role of material *actants* in technoscientific practices. Finally, the third approach is introduced through an equally narrow selection of recent HPS studies into how scientific concepts are *used* within experimental practices.

Sketching these areas of scholarship in such narrow ways obscures valuable scholarship. This sacrifice is intended to concentrate attention on those converging insights emerging from approaches to scientific practices that focus on either material or conceptual elements. To introduce this convergence, I will begin by positioning the two strands of literature mentioned, from STS and HPS respectively, in relation to Pickering's account of the dynamic interactions between material, conceptual, and human elements of scientific practices.[21] In later chapters, this account will be examined further as I explore how concepts can come to be structured as tools for use in pursuing of specific goals.

[21] As noted in the introduction, my account of these strands of STS and HPS literature is an analytic distinction, not a description of disciplinary differences; each contribute to the broader umbrella of historical, philosophical, and social studies of the sciences and technology.

1.1 Scientific Knowledge as both Contingent and Objective

Pickering's view of scientific knowledge is broadly congruent with those advanced within a range of distinct yet intersecting accounts of scientific practice.[22] In its most general form, this view of scientific knowledge is as a collective resource that provides objective accounts of the real world (in the sense of robust and intersubjective explanations of objects/phenomena that exist independently of human access) that are contingent on the conditions (including material, social, and conceptual resources) that contribute to the situations within which this knowledge was generated.

This view of knowledge is evident in the repeated emphasis Pickering places on both the contingency of scientific practices and the ability of the sciences to objectively describe a reality that is independent of human access. For example, Pickering, along with Adam Stephanides (1992, 164), insists that focusing on the contingent *emergence* of scientific practice does not deny the *objectivity* of scientific knowledge. Later, Pickering (1995a, 54) builds on this views to explore how scientific practices can be understood as temporally extended processes that intertwine contingency and structure. To describe these processes, Pickering (1995b, 105) offers an account of a "dialectic of resistance and accommodation [called] the mangle of practice"; an emergent 'mangle' of unpredictable extensions and interactions between both human and nonhuman aspects of scientific practice.

Developing this account, Pickering (1995b, 194) draws on an appreciation of the processes within which "scientific knowledge can be simultaneously objective, relative, and truly historical". For Pickering (1995b, 209), looking backwards in time (instead of forwards) is a way of seeing temporal emergence from another angle. Based on his studies of past scientific practices, Pickering (1995b, 197) argues that "[scientific] objectivity is a property of

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22 While the differences within this range of positions is important, I seek to highlight their similarities. Some context for this choice is available in Appendix 1 (Annotated Glossary) under *realism/ relativism debates*.

the products that temporally emerge from a posthumanly decentered process". To balance this, Pickering (1995b, 204, 209) also argues that – rather than either social relativism or *technical relativism* – the mangle is limited to the 'brute contingency' that is constitutive of scientific practice. Explaining this brute contingency, Pickering (1995b, 209) describes the specific contents of scientific knowledge as "a function of the temporally emergent contingencies of its production". Rather than merely a product of social construction, scientific knowledge offers a robust account of various mind-independent properties of the world.

While focusing on the temporal dynamics of scientific practice, Pickering also describes those slices of time where scientific knowledge is stable. To illustrate these moments of stability, Pickering offers a metaphor likening established scientific knowledge to islands. In contrast to the metaphor of scientific knowledge as reflecting different faces of the same underlying crystal (split along different axes), thinking of scientific knowledge as islands rejects the notion that there is an underlying *static* form of reality waiting to be discovered (Pickering 2015, 126–27). In contrast, contingencies matter to when and where any specific island forms yet – once they emerge *as islands* – these earthy foundations can provide a temporarily stable platform for sustaining diverse terrestrial life forms over an extended period. Likewise, within the longer-term dynamic contingencies of scientific practices, momentarily stable knowledges can *emerge* from unpredictable interactions. Once stable, these contingent structures can similarly offer a reliable foundation for humans to further investigate the mind-independent properties of the world (Pickering 2015, 124–25).

This island analogy sits alongside Pickering's earlier ones: firstly, scientific knowledges emerge from an open-ended *dance* of agency between the various participants (both human and nonhuman) that contribute to scientific practice; secondly, during these dances, each element is *mangled* in unpredictable ways, such that robust and productive knowledge is constructed; and thirdly, knowledge that emerges from this mangle can provide momentarily stable *islands* of knowledge. Mixing these metaphors, these *islands* of knowledge can provide foundations for further *mangled* interactions, within which humans *dance* with the otherness of the world.

Abstracting from these mixed metaphors, Pickering's approaches suggest that stable scientific knowledges can provide accounts of mind-independent properties of the world that – out of all the innumerable possible properties – happened to emerge within specific assemblages of human/non-human interactions. Furthermore, this approach highlights the importance of examining how *emergent* alignments between the human, conceptual, and material elements are required to stabilise a given aspect of scientific knowledge (Pickering 2012). I return to this additional point later. For now, my focus is on presenting Pickering as describing scientific knowledge as providing objective accounts of the real world; accounts that emerge through – and are contingent on – the dynamic co-produced performances between the heterogeneous participants involved in the temporally extended processes that make up scientific practices.

Pickering's view of scientific knowledge can therefore be understood as rejecting two often-contrasted caricatures of scientific knowledge. Firstly, it is a rejection of the view that knowledge is entirely relative to *social* elements of scientific practices. As Ian Hacking (1998a, 213) notes, Pickering can be contrasted with those who focus on 'purely social' approaches, having "always insisted that material things… have active powers of their own which resist research projects". Secondly, this view rejects the ahistorical view of science as proceeding towards a universal view-from-nowhere. These universal view-from-nowhere knowledge positions science as a dispassionately impartial moments of discovery that provide ahistorical accounts of an objective reality. In contrast, Pickering's view of science is as a contingent process that constructs objective and robust accounts of a real world that exists independently of human access.

There are a range of contributions to both STS and HPS that also describe scientific knowledge as simultaneously objective and contingent. While diverse, each is broadly congruent with the view I have attributed to Pickering. For example, as Hans Jörg Rheinberger (2009, 2010a, 13–48) highlights, early-twentieth century accounts of science – particularly those of Ludwik Fleck, Gaston Bachelard, and Georges Canguilhem – emphasised the contingent histories generating the objectivity of current scientific knowledge. Studies of scientific practices since the 1960s also emphasise the localised context-dependence that emerges from both synchronic and diachronic variations in scientific knowledge (Soler 2015, 2–3). Within these, there are conflicting explanations for how these contingencies of practice contribute to scientific knowledge. Of interest here are those that – similarly to Pickering – take seriously the contingencies evident in the variations in scientific practices, while still acknowledging the existence of a mind-independent reality that can be studied scientifically.

These types of views are especially prominent in approaches that examine the materiality of scientific practices. Within this context, interest in the contingencies that contribute to scientific knowledge are often distanced from the human-centric relativism associated with social-constructionism. [23] For example, Galison (1995) explicitly rejects relativism; emphasising that there are a myriad of interacting constraints – material as well as social – that lie behind the strength of scientific endeavours. Similarly, Joseph Rouse (1996, 176) argues that the “the relevant ‘resistances’ to the achievement and maintenance of epistemic alignments within scientific practice cannot be confined to either social or material categories

[23] See Appendix 1 (Annotated Glossary) for more on the need for distancing *constructivism* from *social-constructionism*.

in opposition to the other". Likewise, Karan Barad (2007, 32) includes among the philosophical issues relevant to knowledge-making practices the "relationship between knower and known… the [material, social, and conceptual] conditions for the possibility of objective description [and] 'the nature of reality'…". Meanwhile, Lorraine Daston (2000b, 3 original emphasis) argues that "that scientific objects can be simultaneously real *and* historical"; explicitly positioning a collection of essays on the historically contingent ontologies of scientific objects as standing orthogonal to the plane of the realist/constructionist debates.[24] Meanwhile, and despite their differences, Latour (1993, 6) and Haraway (2000, 110) each explicitly reject both realist expectations of universalism and the relativism of social-constructionism.

Although disagreeing on the details, these and other scholars share with Pickering an objection to the ahistorical 'view from nowhere' notion of a universal scientific objectivity; focusing instead on the objectivity of intersubjective accounts of mind-independent reality. Within these details are a range of arguments for how the objectivity of these intersubjective accounts of reality are generated. For example, in rejecting the traditional 'god's eye view' objectivity, Haraway argues that objectivity can be found at the intersection of multiple situated knowledges (Eglash 2011). This notion of *situated knowledges* stems from Haraway's (2004, 232) critique of the ways observations of scientific reports are presented as objective descriptions, despite relying on a range of unacknowledged contributions that cultivate this illusion of transparency and self-invisibility. For Haraway (2004, 232), the reliance on un-marked others minimises the critical attention on the process of witnessing. As such, the ideal of a scientist as a 'modest witness' – an idealisation constructed as part of the traditional scientific notion of objectivity – ignores that witnessing is always an engaged, interpretive

[24] For discussions on the notion of scientific discovery as a historiographical tool, see: (Arabatzis 2005, 53–69; Dick 2013, 173–200).

and contingent account of experience (Fitzgerald and Callard 2015, 21–22; Haraway and Goodeve 2000, 160–61).[25] Rejecting the possibility of neutral witnesses, Haraway (1991, 1994, 2006) positions objective knowledge as located at the crossroads of multiple partial and situated perspectives of the real world. Yet, far from denying the reality of scientific objects or meanings, Haraway's approach affirms them (Munnik 2001, 110). In doing so, objective knowledge is positioned as generated in scientific practice *via* the situated dynamics of the ongoing practices of being and doing the world (Haraway 2006, 176; Lykke, Markussen, and Olesen 2003, 53–54).

Haraway's situated-knowledges approach provides one way of balancing a recognition of the localised contingencies of scientific practices while maintaining that scientific knowledges can be objective. Other scholars offer alternative ways of achieving this balance. For example Ihde (2012, 371) shifts the site of objectivity away from the unmarked witness and towards the inter-relational ontology of technical practice. In doing so, Ihde (2012, 371) presents robust knowledge as produced through the variational and critical perception of multiple converging technically-mediated results (rather than perspectives). Meanwhile, another possibility can be seen in Isabelle Stengers' development of the notion of 'competent colleagues'. On the one hand, Stengers (1997, 40) argues that "nature cannot be described 'from the exterior,' as if one were an ideal, godlike spectator". Balancing this, Stengers (2011, 374, 377) also argues that the specificity of experimental practices assemble heterogeneous 'competent colleagues' to verify the reliability of scientific facts; producing "things that exist for themselves and by themselves".

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[25] Also see Steven Shapin's (2010, 49) famous argument that the universalist notion of objectivity developed when 'modern knowers' of the seventeenth century assumed they were able to discover an unencumbered knowledge that mirrored nature.

Locating the objectivity of scientific knowledges as emerging from a 'mangle' of practice, Pickering's approach is distinct from, yet congruent with, those presented by Stengers, Ihde, Haraway, and others.[26] For example, John Zammito (2004) develops a hybridisation of Pickering's approach (focusing on the emergent resistances that exist between different elements within scientific practice) and Galison's approach (emphasising the intercalated constraints of various subcultures within scientific practice). This hybrid proposal seeks to offer a "vocabulary that leaves scientific practice neither utterly divorced from its cultural context nor relegated to a mere puppet of other forces" (Zammito 2004, 231). In addition, there are a wide range of descriptions of the contingent generation of objective knowledges that emphasise related elements of scientific practices: examinations into the discontinuity of scientific concepts (e.g., Nersessian 1987); explorations of the unpredictability of scientific practice (e.g., Rheinberger 1994); studies of the independence of some experiments from theory (e.g., Steinle 2010b); and arguments for the value of plurality in scientific practices (e.g., Chang 2012b).

Adding to Pickering's multiple metaphors, the example I want to highlight is Mieke Boon's (2015a, 166) description of constructing a theoretical entity as a process like sculpting marble. This metaphor helps to articulate that not all aspects of scientific practice are contingent and that contingent outcomes are not at all arbitrary (Boon 2015a, 172). Sculpting scientific knowledge is an interactive process of 'carving out' an account of reality. In the case of a sculpture carved from marble, the outcome emerges from a process that is limited by the properties of the marble, the intentions of the sculptor, and the instruments and

[26] Pierre Bourdieu's (2004, 69) account of science as an historically situated site for a closed yet public system that produced trans-historical truths offers another potentially compatible view. However, for Bourdieu (1968, 693) the focus was on *social* elements; presenting scientific practice as a unique social space that should be analysed like other social spaces – in terms (*habitus*, *symbolic capital, cultural capital, etc.)* that highlight the routines and relationships structuring social order independently of individual consciousness.

techniques used to carve – yet is in no way pre-determined by any of these. Likewise, while there are inevitable aspects of the world (such physical properties that exists independently of humans) the material constraints do not necessarily reflect some inherent knowable structure in the world 'out there' (Boon 2015a, 174). As in Pickering's account, Boon therefore positions scientific knowledge as generated from contingent processes that incorporate both the invariant aspects of the world and the interactions between these aspects and other aspects of the world (including us).

These various approaches each demonstrate that it is possible to acknowledge that scientific knowledge is contingent without eschewing the authority that reliable and inter-subjective knowledge offers. When distanced from each other, approaches that draw more on HPS or STS fields of literature tend to extend this view in diverse ways. For example, when contributing to HPS, the rejection of ahistorical objectivity has been carefully balanced with an interest in examining the ways in which science as practiced yields, and has yielded, justified beliefs about a mind-independent world (Grene 1987, 72). Meanwhile, the various anti-essentialist approaches contributing to STS emphasise the sources and interpretations of knowledge and artefacts as complex, multiple, and produced through interactions between the material and social worlds (Sismondo 2010, 11). However, in each case, this same view of scientific knowledge – as simultaneously contingent and objective – has been supported by explorations of the materiality of scientific practice.

It is this focus on the materiality of scientific practice that helps to challenge the universality and invariant progression of scientific knowledge, while simultaneously allowing for the rejection of relativist social-construction explanations for context-dependent scientific knowledge. In the view of scientific knowledge described in these approaches, the contingency of scientific practice can be accounted for without relinquishing the view that scientific facts correspond to a real-world that is independent of human access. Therefore, while disagreeing on other points, these approaches all position scientific knowledge as contingent (and situated within the conditions of its production) and as offering objective (i.e., robust, and intersubjective) accounts of the real world (that exists independently of human access to it and distinct from human perspectives of it).

Balancing the tensions within this view depends on articulating the contingent situations within which scientific facts are generated without undermining the value of these facts as objective knowledge that can help to make sense of the world. This point can be clarified by breaking it into three claims. Firstly, experiments occur within historically contingent contexts, where a range of conditions (including material techniques, scientific concepts, and social institutions) provide the specific dynamics for these experiments to become possible.[27] Secondly, knowledge-claims generated by experiments can only contribute to the body of scientific facts if accepted by relevant scientific communities.[28] Finally, contingent-yet-objective scientific knowledge emerge from an even more temporally extended process that includes both the generation and interconnected justifications of scientific facts.[29] Together, these claims provide a view of experimentally generated knowledge that builds upon – and needs to be integrated within – existing scientific knowledges and practices.

At this point, given I intend to focus on experimental practices that generate scientific knowledge, it is worth reiterating that the line between the processes of generating and justifying scientific knowledge is far from clear. Both processes include a range of

[27] For some accounts that emphasise the conditions of experimentally generated knowledge, see: (Galison 1995; Latour 1999; Pickering 1995a; Rheinberger 1992; Stengers 1997).

[28] For some accounts that look at the dynamics of transforming experimentally generated knowledge-claims into scientific fact, see: (Latour and Woolgar 1987; Law and Williams 1982; Leydesdorff 1991; Star 1983; Thompson 1993).

[29] For example, see examinations into the role of experimental practices within broader scientific practice that have blurred the older lines between the contexts of 'discovery' and 'justification' – for some examples see (Arabatzis and Nersessian 2015; Hacking 1998b; Rheinberger 2010a; Rouse 2011a; Shapin and Schaffer 2011).

interconnected practices: the dynamic interactions generating the first-order knowledge-claims within experimental practices; the complex relationships between experiments and the broader contexts of scientific practices; and the convoluted processes within which some first-order knowledge-claims eventually become accepted as a scientific fact. In line with this, the objectivity of scientific knowledge has been proposed to emerge from intersubjective assessments throughout the various stages of generating and justifying scientific knowledge: including via assessment from multiple partial perspectives and multiple converging techniques.[30] According to this view, the specific form and content of a given scientific fact (about a particular aspect of the world) may have been generated differently under different circumstances yet, when this form stabilises as a fact, it can nonetheless function as a robust and intersubjective account of an aspect of the world.

So far, I have focused on demonstrating how Pickering's approach offers a view of scientific knowledge that is congruent with views that emerge from a wide range of historical, philosophical, and social studies of scientific practices. In the following sections, I will narrow my focus to highlight two specific strands within these broader practices. Firstly, I will sketch some account of material agency within STS that, along with Pickering, seek to decentre humans from descriptions of scientific practice. Secondly, I will offer a complementary tour through some recent HPS approaches that examine how concepts are used in scientific practices. To draw these two areas together, I will then examine Pickering's analogy between conceptual structures and material instruments. In doing so, I aim to demonstrate that STS attempts to decentre humans in accounts of scientific practice by focusing on material agency can be extended – through recent HPS studies into tools (whether material or conceptual) – to consider how disciplined practices can structure the

[30] For example, see my earlier discussion of the approaches take by Haraway (2006) and Ihde (2012).

ways in which concepts are used as goal-directed tools. Therefore, to conclude this chapter, I will outline how Pickering's analogy offers a way to develop an intersection between research within historical, philosophical, and social studies of scientific practice that focus on *either* material or conceptual practices; an intersection I will build upon in the rest of this thesis.

1.2 Material Participation in Scientific Practice

Returning to my focus on experimental practice, it is time to consider accounts of how the *materially* mediated interactions between humans and other heterogeneous participants contribute to the process of generating objective-yet-contingent scientific knowledges. For Pickering (2012) it is the unpredictable emergence of human-material-conceptual interactions that provide the *conditions of possibility* for generating robust, intersubjective accounts of phenomena that exist independent of the ability of human's to observe them. In short, scientific knowledge may be contingent on the *conditions of production* yet still provide ways for humans to interact with instances of this *phenomenon* in more predictable ways.

Another famous account of materially-mediated knowledge production is Bachelard's description of tools as "the material existence of a determinate body of knowledge" (Rheinberger 2010a, 31). Building on this, Rheinberger (1994, 2011) treats 'experimental systems' as a unit of analysis to draw attention to the structured yet unpredictable processes within which the material-semantic carriers of scientific knowledge are produced. This focus on experimental practice allows Rheinberger (2010a, 154) to describe the blurred tension between epistemic objects and their concepts; a tension that can "reach out into the unknown [to] become research tools". Likewise, Rouse (1996, 128–30, 2015, 245) describes experimental systems as constructing reproducible arrangements of a particular aspect of the world through the interacting elements of instruments, technical skills, and object signification. Taking a different approach, Miriam Solomon (2007, 420–21) details how tools can store, and in some cases produce, information that aid humans with various goals – operating as external 'artifactual arrangements' that rearrange the world in a way that can reduce individual cognitive loads.[31] Similarly, as mentioned earlier, Boon (2015a, 167) highlights the role of instruments in science as interacting with humans to carve out scientific knowledges.

While contributing to this wider scholarship on the materiality of scientific practice, Pickering's articulation of *material agency* is most readily understood in relation to accounts of scientific practice that engage with a specific strand of STS literature.[32] While there are important variations, attributing agency to materials is typically intended to highlight that the actions of nonhumans can make a difference in how the world is transformed (Kirchhoff 2009; Knappett and Malafouris 2008). For example, diverse approaches within this strand of research each explore how various nonhuman actants – such as material instruments and laboratory animals – actively contribute in the generation, mobilisation, and stabilisation of scientific knowledges (e.g., Haraway 2006; Ihde 2009; Latour 2005; Law and Mol 2008; Robins 2008).

While there are other examples, I will focus on the work of three scholars already mentioned – Haraway, Ihde, and Latour – who each share with Pickering an interest in the role of material nonhumans as non-neutral participants in the production of scientific knowledge.[33] Each these scholars highlight the materiality of scientific practice in unique

[31] In this context, tools are can be considered, broadly, to capture epistemic units that are used in the pursuit of various goals. Therefore, although Solomon (2007, 420–21) defines tools here as artefacts or material constructs this definition allows a broad understanding of 'material' to include knowledge artefacts such as the World Wide Web.

[32] As discussed under *material agency* in Appendix 1 (Annotated Glossary), a range of further questions raised by this notion are outside the present scope.

[33] For example, Karen Barad (2007) offers another variation on the value of developing post-humanist performative accounts of the contributions of non-humans to emergent technoscientific practices.

ways (Casper Brunn Jensen 2003b, 229–30). In presenting each, I will concentrate on how each of these scholars distinguish between human agency and material agency. In doing so, I aim to illustrate the value of examining how the non-intentional actions of nonhumans can contribute to scientific practices.

Of these scholars, Ihde describes the most straightforwardly asymmetrical relationship between human and material agency. As with Haraway, Latour, and Pickering, Ihde offers a view of human-technology interactions as allowing for possibilities that are non-neutral.[34] A key point of difference is Ihde's description of the *constrained* agency with which material-technologies contribute to these non-neutral possibilities.[35] For example, Ihde (2009, 75) draws on the history of technically-mediated astronomical sciences to argue that "changes in technologies produces changes in what and how ideas are communicated". However, Ihde (1979, 15, 41, 56) also argues that the material agency emerges unpredictably within the temporally-extended interactions with humans and, therefore, that technologies are quasi-others that should be understood in relation to the self-experience of humans. In this way, these quasi-others can be neither dismissed as merely tools nor rarefied as animate entities (Ihde 1979, 40).

Within this account, Ihde draws attention to a distinction between mere tools and animate entities – while the former operates as an extension of human intention, the latter are autonomous. Within this distinction, machines can operate in ways that are both more than an extension of human intention even while not being an autonomous other. To clarify this point, Ihde (2003, 140–41) describes the directions of transformation that emerge from

[34] Note that Ihde (2009, 75) is careful to clarify that while *non-neutral*, material-human interactions are "also short of anything like determinism".

[35] For Ihde (2003, 140–41) a distinction should be maintained between 'subjects' and 'objects'. In contrast, Haraway claims that within "the epistemological bounds of technoscience, subjects and objects themselves no longer remain discrete and exclusive"(Eason 2003, 172) – also see (Haraway 2004, 3).

the relations between humans and quasi-other machines as asymmetrically bidirectional. In this relationship, artefacts and instruments are not able to change in their relations with humans to the same degree as those changes that humans undergo in their relations with technology.

Where Ihde emphasises the differences between human and nonhumans, Latour argues that human and nonhuman contributions to knowledge production should be approached as symmetrically co-produced (Ihde and Selinger 2003, 5). For example, Latour (1999, 214) describes nonhumans as 'fully-fledged social actors' that exist alongside humans within sociotechnical interactions. This focus on symmetry can also be found in Latour's (1992, 233, 254) figuration of assemblages, where different sections of an intended action are delegated to any combination of human and material actants. These 'assemblages of actants' interact within a complex distribution of competencies and performances such that it is not possible to study any part independently (Casper Brunn Jensen 2003b, 228, 230).

However, Latour (1999, 76) makes clear that this is not a serious proposal for the establishment of a full symmetry between humans and nonhumans. Instead, this emphasis on symmetry can be considered an analytic approach for drawing attention to a shared feature: each act in the world (and on one another). This caveat can be clarified with three points. Firstly, Latour (1999, 212) describes nonhumans as having their own histories that enforce an order to the way that human and nonhuman properties are able to be exchanged: none are swapped haphazardly. Secondly, Latour (1993, 107–8) argues that 'principles of symmetry' should be used when analysing human-nonhuman interactions because it is impossible to analyse any part of an assemblage in isolation. Thirdly, symmetrical analyses of humans and nonhumans helps to avoid imposing a spurious asymmetry (Latour 1999, 76). Rather than presupposing differences between human and nonhuman actants (and their histories), Latour (1993, 103, 107–8) is interested in locating these differences so that we can understand how some collectives dominate others.

Haraway's (2006, 175) account of instruments as 'full partners in the infoldings of worldly embodiment' shares a number of similarities with Latour's (1999, 214) description of instruments as 'fully fledged social actors'. Indeed, Haraway (2006, 185–86) shares Latour's view of humans and nonhumans as making symmetrical demands on one another. In addition, Haraway description of symmetry is also tempered with a caveat: although intermeshed in symmetrical relationships, the historicity and situatedness of worldly practice mean that the content of these demands are asymmetrical in practice (Lykke, Markussen, and Olesen 2003, 53–54; Haraway 2006, 165–86). Similarly, Haraway share Latour's approach of including a wide range of entities within the category of nonhuman actants – such as non-human animals and machinic-nonhumans – that contribute to the sociotechnical interactions that produce knowledge.

In further exploring the diverse possibilities of human/nonhuman relations, Haraway offers a valuable collection of analytic concepts for the hybrid assemblages that can emerge through multiple human/nonhuman interactions. For example, Haraway's (2006, 176–85) account of a *Crittercam* describes a composition made of human scientists, nonhuman-animals, and various technological equipment.[36] Bringing these actants together, the Crittercam produces audio-visual data that, via interpretation by another collaboration between humans and machinic-nonhumans, contributes to knowledge about the environment and animals being studied (Haraway 2006, 176–85).

[36] A Crittercam is compact device that can be attached to a wild animal to capture video and audio recording along with a collection of environmental data such as depth, temperature, and acceleration.

Within this type of description, the category of human and the various categories for nonhumans are not referring to actual things in and of themselves – rather, such terms are positioned as dependent on relational interactions (Haraway and Goodeve 2000, 25). In this way, Haraway's approach provides a view of humans as one of many material-semiotic entities that are all immersed in particular historical identities based on their unique relations to other material-semiotic entities (Haraway and Goodeve 2000, 25). In doing so these encounters of enmeshed bidirectional transformations are positioned as processes through which knowledge is produced (Haraway 2004, 225).

Also focusing on scientific practices as processes, Pickering (1995b, 67) offers an account of the real-time reciprocal 'tuning' of human and material agency. This 'dance of agency' is a negotiation between partners that, while differing in kind, interact in such a way that each is equally liable to reconfiguration during the process. For Pickering (1995b, 17–18), this difference in kind is important because human agency involves time-dependent intentionality (plans and goals) while material agency does not. As such, human agency and material agency are neither equivalent nor interchangeable. However, while human agency has intentionality, human intention is not in control (Pickering 2006b, 213, 217). Meanwhile, although not able to be controlled or directed by human intention, captured material agency can be watched by human agency (Pickering 1995b, 67). As such, asymmetry arise because human agency includes temporally-extended intentionality, while material agency does not (Casper Brunn Jensen 2003a, 88; Pickering 1995b, 18–19).

In developing this argument, Pickering (1995b, 23) provides a view of scientific practice as involving the delineation and reconfiguration of machinic captures, human intentions, and real-time practice, through a goal-oriented dialectic of resistance and accommodation between material and human agency. In this, Pickering describes material instruments as the embodiment of material agency (that is, the embodiment of the forces of the material world that produce effects on the world).[37] Therefore, from the asymmetrical perspective of humans, forces of the material world resist the goal-oriented intentions of human agents.

In this context, resistance only makes sense from the perspective of the human agent, and "denotes a failure to achieve an intended capture of agency in practice" (Pickering 1995b, 22).[38] Likewise, it is from the perspective of the human agents that these impediments to their intentions need to be accommodated. For example, in order to accommodate the difficulties presented by this embodiment of material agency, human agents can make choices – including revising the aim of the experiment, making technical adjustments, and initiating changes in social relations (Pickering 1995b, 21–22). Once these choices are made, there is once again a period of human passivity during which the impact their actions on the outcomes of the experimental setup need to be determined. This sequence of activity-then-passive participation continues with each participant switching back and forth in relation to their dancing partner(s). Eventually, a point of interactive stabilisations (between the human, material, and conceptual elements involved) is enough for human agents to end the experiment. I will return to the conceptual elements in this dynamic later.

Focusing on human and material dancing partners, Pickering insists that there cannot be a straightforward substitution of one partner for another.[39] However, while not of the same kind, the human/material interactions are between equals (in the sense that each has agency) and their emergent properties are necessarily intertwined (Pickering 1995b, 18–19).

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[37] Like Ihde, Pickering (1995b, 158) makes a distinction between tools and machines. However, as discussed in Chapter Two, this distinction can be set aside in this context, because Pickering considers both tools and machines as embodying material agency in a way that resists human intentions.

[38] See Appendix 1 (Annotated Glossary) for more on how *resistance* is used in this context.

[39] While human actants and nonhuman actants can be physically substituted (say by replacing human fruit pickers with an automated harvester or vice versa), it is not a straightforward substitution; the emergent dynamics would alter as the interactions between the new collections of participants found coherence.

For example, say a group of scientists (intentional agents) build a machine to achieve a goal. In using this machine, the scientists adopt a passive role to measure or observe a physical process. During the phase of passive human enquiry, the materiality of the world acts – "doing whatever it will, quite independently of human goals and desires" (Pickering 2012, 318). These actions of the world may resist the intentions of the humans involved in the dance. For example, perhaps the machine used to investigate a given phenomenon does not operate as expected or produces an unexpected result. In response to the material resistance that the machine captures in this way, the scientists can then accommodate this material agency (in any number of ways, as discussed earlier).

It is important to note that scientist have no way to know if any given resistance is an artefact of the experimental design, or an indication of something unexpected within material reality that they need to account for. Therefore, this accommodation involves an active choice: perhaps the machine is modified, the experimental set-up is changed, the scientific concepts questioned, or the theoretical assumptions reviewed. Alternatively, this resistance may be taken as relevant data about the world and the initial aims and methods of the experiment modified to take this into account. Following whichever accommodations are made, material agency once again resumes its active role. The iterations of this 'dance of resistance and accommodation', as Pickering repeatedly calls it, each contribute to the slow reconfiguration of the both human and material performances. This reconfiguration generates scientific knowledge in unpredictable ways that are interactively tuned to each other; a tuning process with dynamics that are outside the control of any of the participants (Pickering 1995b, 7, 21–22).

As already discussed, Pickering (1995b, 7, 21–22) regards these real-time processes as resulting in temporally extended and unpredictable productions of robust knowledge that are nonetheless contingent on the historically situated paths that led to the state of knowledge at the moment of analysis. For Pickering (1995b, 65–67), this approach provides a way of shifting the focus away from both human intention and the notion of constraint as a synchronic characteristic of human agency. To do this, Pickering (1995a, 67) argues that constraints emerge *between* human and material elements in science and are equally open to be mangled in the dances of resistance and accommodation that occur in practice.[40]

In this way, Pickering (1995a) draws attention to the diachronic processes of resistance and accommodation between the various elements of scientific practices within which islands of scientific knowledge can emerge. Furthermore, it is through the interactive stabilisation between each of these elements that points of stability can be generated within the goal-oriented yet unpredictable dance between human and non-human performances within scientific practice. For example, Pickering (2012) describes the robustness of stable scientific knowledge as an emergent product that is contingent on the intertwined contributions of human intention and material resistance. In this way, the islands of stability that emerge in these dynamic practices can provide robust descriptions of objects/phenomena (Pickering 2015, 124–28).

The simultaneous historicity and temporal emergence of scientific knowledge form a central focus in Pickering's (2003, 100) descriptions of the "historicity and becoming of machine-human couples". As part of this, the multiplicity of entities and their relations are presented as simultaneously 'being' and 'becoming'. According to this view, there can be both weakly and strongly coupled trajectories of becoming. In addition, the strength of a currently coupled set of entities does not determine the future becoming of any of the entities within the set (Pickering 2003, 97–99). Of course, the more strongly coupled the trajectory

[40] Pickering refined this articulation in order to distinguish his notion of 'resistance' from the notion of 'constraints' used by Peter Galison and others (Pickering 1995b, 65–67, 1995a, 43, note 1; Galison 1995, 27, note 7).

of becoming was for a given set of entities in the past, the more likely they were to form an assemblage in the present. However, because the continual becoming of these entities is in an open-ended process, the future emergence of these entities remains indeterminable. As such, although not determined by them, the future *becoming* of a given entity still depends on the relations that *being* requires in at that moment. In this way, the becoming of material instruments depends on human actions and human becoming depends upon materials instruments (Pickering 2003, 100).

Understood in this way, Pickering's account of the interactions between humans and material nonhumans are congruent with those sketched for Haraway, Ihde, and Latour. Like Haraway, Pickering (1995b, 185) positions human and nonhuman actants as simultaneously distinct and entangled depending on the analytic frame. Pickering's approach can also be positioned as congruent with both Ihde's asymmetrical view of human/nonhuman relations, as well as Latour's argument that differences between human and nonhuman actants, and their histories, should be located rather than presupposed. In the first case, Pickering is careful to distance himself from a strict symmetrical understanding of human-nonhuman relations by arguing that, while there is symmetry in bi-directionally transformative interactions of human and nonhuman agency, these agencies are asymmetrical in kind, with neither reducible to the other (Casper Brunn Jensen 2003b, 229–30).[41] It is by viewing entities at a given time, and as functions of their situatedness and their path-dependence up until that point, that these relative distinctions can be made (Pickering 2003, 97). In the second case, Pickering (2003, 97, 101) relaxes this categorical distinction when talking about machine-human couplings continually 'becoming' through temporally-extended entangled interactions. That is, when viewed over an extended period of time the process of this

[41] Pickering (2003, 97) maintains that this distinction is significant partly because he does not want to reduce entities to their relations.

intertwining of emergent properties is a function of its past historicity and future emergence such that interactions erode the distinctions between the categories (Pickering 2003, 112). In this way, Pickering shares views with Latour, Ihde, and Haraway that – despite the asymmetries – neither humans nor nonhumans should claim a central place in interpretations of the emergent interactions of scientific practice.

While only a brief tour through a small selection of examples, these four accounts of material agency highlight the value of shifting the frame of analyses away from human actors to examine the active role of nonhuman elements of those practices that generate knowledge. This approach includes shifting away from both the focus on the intentions of human actors and the view of constraints as external barriers that limit scientific practice. This does not mean that the intentions of researchers are unimportant, or that the notion of constraint, if construed as fields of possibility, is not valuable. Indeed, rather than replacing studies of these elements of scientific practice, the post-humanist approaches above provide examples of how paying attention to nonhuman participants in scientific practices highlights an additional consideration. Namely, that there is value in analysing how nonhumans contribute – by resisting human intention within experimental practice (in ways that are unintended, emergent, and largely unrecognised) – to the conditions of possibility within which experimentally generated knowledges emerge.

Therefore, while it may not be possible to foresee the emergent outcomes of the heterogeneous interactions that generate scientific knowledge, it may be possible to identify past contributions of specific heterogeneous interactions. Doing so may even offer avenues for recognising potential variables that might contribute to evaluating the robustness of current scientific knowledges. Furthermore, while this insight highlights the actions of material participants, Pickering's account of conceptual structures provides a way of considering non-material nonhuman contributions in an analogous way.[42] In particular, I am interested in this extension as a way of exploring the role of scientific concepts in experimental practices. I will return to this point towards the end of this chapter (and explore it in more detail in Chapter Two). However, before doings so, it is important to appreciate another strand of research within the broader contributions to historical, philosophical, and social studies of scientific practices: accounts of concept-use in experimental practices.

1.3 Conceptual Contributions to Scientific Practice

At first glance, scientific concepts appear of minimal interest to STS accounts of the role of material agency in the processes by which scientific practices construct knowledge and artefacts.[43] As noted earlier, within this context empirical scientific practices are often contrasted with the conceptual practices of theorising (Casper Bruun Jensen 2014, 200). This dichotomy positions concepts as an aspect of theorising: an aspect of human-participation not relevant to the materiality of scientific practice.[44]

This disinterest in the role of concepts in experiments is also evident within the broader shift towards historical philosophical examinations of the dynamics of sciences *as practiced* that gained momentum in the 1980s. This 'turn to practice' was often an explicit attempt to balance the previous emphasis within Philosophy of Science on scientific theory and

[42] For example, the notion of material agency to describe concepts as agents that "operate in and on the empirical" has been taken as a point at which to explore the possibility that "the empirical is itself conceptual in multiple ways" (Casper Bruun Jensen 2014, 200)

[43] This is consistent with broader trends within STS (Sismondo 2010, 11). When examined in this context, concepts are discussed primarily terms of their role in the representation of knowledge during the mobilisation and stabilisation of scientific facts (e.g., Bowker and Star 2000, 152).

[44] For example, introducing a symposium published within the interdisciplinary journal *Common Knowledge* it is noted that "It is conventional in STS to view nonhumans as well as humans (and thus our concepts too) as historical changing actors" (Casper Bruun Jensen et al. 2011, 9).

conceptual change.[45] As part of this shift, Ian Hacking (1983, 105, 158) was influential in highlighting ways in which experimentation has 'a life of its own' that proceeds theory. While valuable, these approaches maintained a dichotomy between scientific theory and scientific experiments, with concepts placed firmly within the domain of the former.

The placement of concepts as a representational element of theory is consistent within the philosophical view dominant at the time. Traditionally, scientific concepts were considered vessels for the products of science, rather than implicated in the dynamics of experimentation (MacLeod 2012, 47). In line with this view, standard approaches to the role of concepts in experimental practice relied on a view of concepts as language-based representations of the products of scientific practice (such as *theories*). In an example of this traditional view of conceptual practice, Kevin Dunbar (1997, 465) described the 'conceptual life of a laboratory' as the gradual and often undocumented evolution of representing and communicating how ideas emerge from experimental practices. In doing so, Dunbar (1997, 469, 489) describes the ways that scientists collaborate using multiple specific analogies that operate in conjunction with other reasoning mechanisms to link 'base' knowledge and 'target' problems in the gradual development of new concepts. In this type of view, concepts provide a way of representing ideas that emerge from the experimental process – concept are not seen to intervene in the experiments themselves.

While interest in analysing concepts remains rare within STS, the traditional view of scientific concepts has been increasingly challenged within HPS. These challenges highlight that concepts are used in scientific practices in ways that extend beyond their roles as merely mental or linguistic representations (Nersessian 2012, 246; MacLeod 2012, 50). Furthermore,

[45] This emphasis on theory is associated with the influential accounts of science by Karl Popper and Thomas Kuhn that focus on the processes of accepting or rejecting the *results* of experiments (Chalmers 1999, 130).

this insistence that concepts are used for more than representing knowledge provides a way of extending beyond the standard debates around the meaning and reference of concepts as used in scientific theories.[46] In doing so, these various approaches help shift the focus towards examining both *how* concepts are used in scientific practice, and what concepts are used *for*.

This renewed interest in concepts can be understood, in part, in relation to the broader move within HPS to review the dichotomy between theory and practice discussed earlier. This process of review is especially evident in those historical accounts of scientific practice that highlight the role of theoretical *artefacts* – such as mathematical formulas, pictorial or schematic representational tools, and three-dimensional models – in scientific practice (Catinaud and Wieber 2014, 157).[47] These studies help to rectify the unfortunate separation of theoretical and experimental practices within the early turn to practice (Woody 2014, 124). In addition, they highlight the role of materiality in mediating the interactions between explanatory discourse and *experimental investigations*. For example, Ursula Klein (2001, 276) demonstrates that, within the history of chemistry, "theory entered experiments via a reified sign system and its skilled manipulations" rather than in the form of propositional based hypotheses.

Within this context, examining the active role of concepts in scientific practices provides an approach that complements these important questions about materiality. This avenue is highlighted by recent work on the uses of concepts: specifically, those examining the role of concepts in mediating the interplay between theoretical and experimental practices (e.g., U.

[46] These debates include those on the meaning and reference of concepts; conceptual change in relation to scientific theories; and the role of concepts within the relationship between theoretical and observational vocabulary.

[47] For some examples, see (Heersmink 2013; Knuuttila and Voutilainen 2003; Nasim 2013; Woody 2014).

Feest 2012, 183; Bloch 2012a, 209); the uses of concepts in theoretically polyvalent ways (e.g., Arabatzis and Nersessian 2015; Schmidgen 2014); and the contributions that concepts can make to experimental research in ways that are not determined by the theoretical frameworks within which the concept might also be embedded (Arabatzis 2012, 162).

These accounts of concept-use demonstrate that concepts can operate as more than cognitive or linguistic representations. They suggest that – like material representations of explanatory discourse such as theoretical artefacts – concepts can be uses as tools that actively contribute to the dynamics of scientific practices. Within this context, concepts can be understood as contributing to experiments in addition to, yet in distinct ways from, their more recognised roles within theories.

At this point, I should clarify that I am adopting a view of scientific concepts as dynamic bodies of knowledge that have been accrued by communities with specific shared practices (rather than an element of either individual cognition or major social systems of thought).[48] This view reflects accounts of scientific concepts *as used*. For example, Feest (2010, 173) describes how the available body of knowledge of a given class of phenomena conceptualises the delineation between these phenomena and other classes of phenomena. Put in more traditional language of reference and meaning, individuating scientific concepts requires distinguishing between individual concepts within complex situations – where the function of concept marks out, and clarifies its explanatory role for, a specific part of a problem situation sufficiently to support a belief about the ontological status of that function (Andersen and Nersessian 2000, S232, S235). However, rather than simply review the role of concepts in *belief* about a given referent, Feest's focus is on how concepts are *used* to investigate phenomena regardless of such beliefs. For example, Feest (2010, 173) argues that,

[48] See Appendix 1 (Annotated Glossary) for my use of *scientific concepts* and *bodies of knowledge*.

once delineated, individuated instances of a type of phenomena can be conceptualised in a way that provides a tool for investigating the type of phenomena directly. Expanding on Feest's approach, Bloch (2012a, 192) suggests that, through the articulation provided by operational definitions, concepts can function as preliminary articulations that condense and integrate scientific knowledge in ways that allow for the isolation of instances of a given phenomenon. More specifically, Bloch (2012a, 215) demonstrates how definitions operate to integrate knowledge using characteristics that are considered causally-fundamental to the phenomena in question within the scientists' context of knowledge.

As such, rather than picking out eternal natural kinds, definitions of scientific kinds can be considered contextual – developing along with those characterisations of the phenomena that are themselves evolving within the changing available knowledge (Bloch 2012b, 239). Given this, it is important to recognise that, unlike theories, concepts are not explanations in and of themselves. As Steinle (2010b, 36) points out, concepts are neither true nor false and can only by judged as appropriate, or not, in relation to their use for a given purpose. Viewed in this way, individual concepts can therefore be seen to play useful roles in scientific conceptual hierarchies even if they fail to pick out an eternal natural scientific kind (Bloch 2012b; J. McCaffrey and Machery 2012; C. K. Waters 2014).[49] Indeed, as Brigandt (2010, 25) argues, the use of concepts can be understood as constituted by the three dynamically interacting components – referential targets, inferential associations, and epistemic goals – that each provide a means of individuating concepts.

Furthermore, in line with the view of scientific knowledge as simultaneously objective and situated, concepts can be neither reduced to their referents nor dismissed as mere social

[49] In relation to this, empirical research in cognitive psychology supports family-resemblance accounts of concept formation as a process of framing structural connections rather than picking out ultimate natural kinds (Andersen, Barker, and Chen 2006, 45).

constructs (Kindi 2012, 30, 36). While flexible, a concept cannot be altered purely because humans wish it to be so. Instead, the use of a concept involves the rough, locally contingent unfolding of historically dynamic patchworks that offer resistance to their intended use (Kindi 2012, 37). To borrow Nancy J. Nersessian's (2012, 245) words:

> "concepts are dynamic and socio-cultural in nature… they are neither completely fixed units of representation nor solely mental representations, but arise, develop and live in the interactions among the people that create and use them… in historical processes… spaning generations of scientists".

These approaches to studying the uses of concepts sidestep some of the problems associated with a view of concepts as deriving their meaning from the totality of theoretical assumptions about their referents (U. Feest and Steinle 2012, 4). In particular, although offering a range of views on the interconnectivity between theory and experiment, investigations of conceptual practice all highlight the value of investigating the functions of concepts over and above their role in linguistic or mental representations (MacLeod 2012, 50; Nersessian 2012, 246).[50] In doing so, these approaches take seriously the arguments that definitions do not fully capture concepts (U. Feest and Steinle 2012, 3). Indeed, as Vasso Kindi (2012, 25) argues, allowing that concept-use does not require definitive boundaries enables investigations of conceptual practice that avoid the problems associated with requiring stable reference between a scientific concept and the object it describes.

Often this interest in conceptual practice has focused on the dynamics of conceptual development. However, recent studies of concept-use also provide a foundation for considering how the uses of momentarily stable concepts contribute to the dynamics of

[50] These approaches also parallel recent work within the philosophy of science around whether the concepts used in science are value-laden. For example, Emma Baitz (2015, 64–68) draws on the work of Dupré (2007), Canguilhem (1989), Méthot (2013), and Kingma (2007) to argue that the normativity of a concept is integral to its use in scientific inquiry.

experimental practices. For example, Uljana Feest (2010) describes concepts as tools for experimentally intervening in the study of phenomena. In this context, tools are devices that, whether physical or not, "enable us to do something" in ways that generate data – and therefore knowledge – within scientific practice (U. Feest 2010, 180–81). To support this approach, Feest (2010, 181–82) argues that concepts are analogous to data-generating instruments such as microscopes and thermometers. This analogy highlights that concepts can be used to measure whether a given phenomenon is present, or to explore "the very nature of a given phenomenon" (U. Feest 2010, 181–82).

By investigating how concepts are used in experimental investigations it has also become possible to examine what concepts are used for (Brigandt 2012, 78; Steinle 2012, 107; MacLeod 2012, 68). Concepts are often of interest because they are used to pursue specific goals, such as generating knowledge (epistemic goals) about the object or phenomena of investigation. When it comes to investigating phenomena, the knowledge sought is often intended to 'make sense of' the phenomena within a given domain of knowledge in some way (such as the classification, quantification, or explanation of the phenomena in relation to that domain). In some cases epistemic goals are disciplinary specific problems – such as the goal of explaining cell-cell interaction in cell-biology – and change over time within that context (Brigandt 2010). Alternatively, an epistemic goal might be to explain a collection of unexpected phenomena – such as the goal of finding a regularity for predicting the attraction/repulsion of electrically charged objects (Steinle 2010b).

These diverse approaches to examining concept-use each highlight the value of examining how the contributions of concepts to scientific practice extends beyond their representational roles. As Steinle (2012, 124) argues, studying the dynamics of using concepts for pursuing specific goals provides a promising way "to obtain an enriched understanding of the knowledge-claims of the empirical sciences…". In addition, as I will argue in the next chapter, these approaches help to highlight how concepts can actively contribute to experimental practice.

1.4 Converging Themes in Studies of Material and Conceptual Practices

When it comes to analysing scientific practices, STS accounts of nonhuman agency are not immediately relevant to HPS research into the uses of scientific concepts – or vice versa. On the one hand, approaches within STS offer limited strategies for analysing how concepts are used as tools for reaching specific epistemic goals. Meanwhile, the notion of nonhuman agency does not feature within recent HPS accounts of concept-use. However, these two approaches are broadly compatible, offering complementary insights about the value of examining the contingent dynamics within which objective scientific knowledges are generated. For example, recent HPS approaches to examining concept-use have been described as "quite compatible with the notion of concepts as participants in the investigative practices of scientist" (Nersessian 2012, 245). The choice of 'participants' in this sentence hints at how this interest in the use of concepts might productively converge with the STS accounts of material participants in experimental practice discussed above. This notion of participation highlights that recent HPS approaches to concept-use are positioning concepts as directly implicated in the dynamic practices that generate empirical knowledge. For example, these HPS approaches focus on how concepts contribute to the dynamics of experimental research (MacLeod 2012, 47). This focus has drawn attention to the functions of concepts as tools and, in relation to this, the epistemic goals that concepts are used to pursue (Brigandt 2012, 78; Steinle 2012, 107; MacLeod 2012, 68).

An exception to the lack of interest in concepts within STS accounts of nonhuman contributions to experimental practice, is Pickering's (1995b, 2006a) notion of conceptual structures. This notion extends accounts of material-human couples (discussed above) to consider other human-nonhuman couples contribute within the emergent transformations of the material, the social, and the conceptual layers of scientific practice. I will examine this notion further in Chapter Two. For the present purposes I will briefly illustrate how this notion provides a foundation for bridging accounts of material and conceptual contributions to experimental practices.

The notion of conceptual structures provides a way of emphasising that conceptual elements of scientific practice are distinct from both the social (human) and material elements of scientific practice; each of which are equally involved within the emergent dynamics of generating knowledge. To explain this, Pickering (1995b, 117) describes conceptual structures as operating within scientific practice as the embodiment of what he terms *disciplinary agency*. For Pickering (1995b, 29, 115–16, 142) disciplinary agency denotes the actions that the 'machinelike' routines of disciplined human performances have on the world. This disciplinary agency is embodied by conceptual structures: disciplined routines that structure conceptual associations in ways that become institutionalised – carried along by collective routine human performances in ways that are independent of human intention (Pickering 2006a, 254). Therefore, although emerging through human performances, disciplinary agency is of a different kind to the intentional agency of humans. In relation to this, I will focus on Pickering's (1995b, 29, 70) analogy between conceptual structures (that capture disciplinary agency) and material instruments (that capture material agency).

While not suggesting equivalence, this analogy highlights the value of examining the unforeseen contributions to knowledge from both material and conceptual elements of scientific practice. However, the potential links between material and conceptual contributions to scientific knowledge that Pickering highlights have been somewhat obscured by the focus on materiality within STS. At the same time, Pickering's account of conceptual structures does not neatly fit into the recent approaches to examining conceptual practice within HPS. Instead, Pickering's notion of conceptual structure offers a tantalising foundation for bridging between STS accounts of material participation and HPS accounts of conceptual practice. I will examine this foundation in the following chapter.

In this chapter, my aim has been to situate Pickering's approach between two specific strands within the fields of STS and HPS respectively. As such, I have not sought to present a comprehensive review of either STS or HPS literature; nor have I intended to offer any sustained criticism of the approaches presented. Instead, I have presented these positions together to examine the *intersection* between accounts of the active roles of material participants in scientific practice (particularly those within STS) and the recent interest within HPS into examining the use of concepts in experiments. The convergence of these strands helps draw together three themes I seek to develop within historical, philosophical, and social studies of scientific practices: the emphasis on examining material non-human contributions to knowledge; explorations of concept-use in experiments; and an interest in the historical conditions within which current practices emerge.

Building on this in the next chapter, I will examine Pickering's notion of conceptual structures in more detail; disentangling it from similar terms and positioning it in relation to other accounts of conceptual practice. In the process, I will propose that the uses of concepts as tools are structured for pursuing specific goals through experimental investigation. It is this proposal that will be further examined and developed through my own research (presented in Chapters Three onwards).

2 Structuring Concepts for Use as Goal-Directed Tools

Complementary themes emerge from *STS* and *HPS* accounts of scientific practice (Arabatzis and Schickore 2012, 399). I am concentrating on drawing together literature on three such themes: the material contributions to knowledge; the uses of concepts in experiments; and the historical conditions within which current practices emerge. In Chapter One I proposed that Pickering's notion of conceptual structures provides a productive foundation for building on this intersection. In this chapter I seek to further develop this proposal. I will begin by examining Pickering's account of conceptual structures in relation to other accounts of scientific conceptual structures. With this terminology clarified, I then seek to demonstrate how Pickering's analogy (likening conceptual structures with material instruments) helps to draw attention to the converging insights in accounts that focus on either material or conceptual elements of scientific practices.

In building on these converging insights, my aim is to propose an additional avenue for investigating how specific sciences are practiced. This avenue focuses on examining how concept uses are structured as tools for pursuing epistemic goals through experimental investigation; tools that contribute to experiments in ways that are analogous to, yet not equivalent with, the active contributions of material instruments. Therefore, I will conclude this chapter with a brief outline of how this avenue can aid in examining the individual experimental practices. Specifically, those fMRI experiments practices documented as generating diverging knowledge-claims from equivalent SLMP-neuroanatomical-correlates. In doing so, I will argue that the interdependently structured uses of two scientific concepts – mental imagery and hallucinations – can operate as independent tools that actively contribute to the knowledge generated within neuroimaging experiments.

2.1 Conceptual Structures as the Embodiment of Disciplinary Agency

In discussing the uses of concepts in generating scientific facts, Pickering (1995b, 113) asks why concepts are not simply 'putty in our hands'. The notion of conceptual structures offer one answer to this question; pointing to how *structured associations* form to align, and translate between, the heterogeneous elements of scientific culture (material, human, and conceptual) (Pickering 1995b, 29, 115–16, 146). Pickering offers a wide range of examples for such conceptual structures. Of these, I am most interested in the structured associations carried along by those concepts that are stable enough to contribute to investigations of specific types of phenomena within a given context. Examples of 'stable enough' concepts include such things as quarks, genes, and the magnetic poles as they are used to investigate specific types of phenomena in quantum physics, molecular genetics, and the geological sciences respectively.

A key feature in Pickering's (1995b, 115) description of conceptual structures is that their roles embody 'disciplinary agency' – that is, there are actions that emerge from disciplined human performances that carry conceptual practice along independently of human intention. For example, Pickering (1995b, 115) highlights how systems of concepts "hang together with specific disciplined patterns of human agency… that carry human conceptual practices along, as it were, independently of individual wishes and intents." It is through these disciplined practices that conceptual structures can come to embody systematic 'machine-like actions' that carry routine conceptual associations into experimental practice (Pickering 1995b, 142–44). Within experimental practice, this disciplinary agency can contribute to the production of scientific knowledge through the framing of machinic performances via their alignment with conceptual structures (Pickering 1995b, 97, 2006a, 254, 2015, 126).

The beginnings of these descriptions of conceptual practice can be seen in an earlier article by Pickering (1982) that extends Thomas Kuhn's description of 'exemplars'. For Kuhn (1970, 186–94) 'exemplars' are the application of shared 'concrete problem-solutions' through which the tacit knowledge of the professional community is learnt.[51] These shared exemplars form one aspect of the broader notion of the 'disciplinary matrix' of ordered elements within a professional community (Kuhn 1970, 182–91). Both the specifics of exemplars and the broader disciplinary matrix are included within Kuhn's (1970, 1974) notion of paradigms.[52] These exemplars describe the formalised ways with which individuals and groups use certain types of concepts within the matrix of ordered elements provided by their scientific community (Andersen and Nersessian 2000, S225–26; Barker 2011, 462).

Pickering explicitly draws upon Kuhn's notion of exemplars. However, in contrast to Kuhn, Pickering positions the formation and use of exemplars as a dynamic process that emerges over time; a process that goes beyond their role as concrete demonstrations that relate a new concept to the world. For example, Pickering (1982) argues that exemplars can also undergo a process of construction and elaboration such that the conceptual associations eventually become institutionalised. During this process, concepts are isolated from the dynamics of their production – becoming entrenched in the practices of diverse research groups such that they can be perceived as representing a correspondence to the material world (Pickering 1982, 127).

It is these dynamic processes that are taken up in Pickering's later description of conceptual practice. As with Pickering's account of material agency (discussed in Chapter One), this description focuses on *resistance-accommodation dialectics*. In this context, the series of

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51 See Appendix 1 (Annotated Glossary), for disputed uses of *tacit knowledge*.

52 Although initially resembling scientific specialisation, Kuhn (1962, 1970, 1974) later clarified that paradigms include a 'disciplinary matrix' of ordered elements within a professional community; exemplary models of past achievements forming one of the many components of this matrix.

interactions articulated are between human intention and the force of disciplinary agency – that is, those actions through which the 'machine-like' routines of disciplined human performances impact the world (Pickering 1995b, 29, 115–16, 142). In this way, disciplinary agency provides a notion for describing how disciplined human performances are shaped by "particular routinized ways of connecting marks and symbols with one another… acquired in training and refined in use" (Pickering 1995b, 115).

As noted earlier, Pickering's notion of disciplinary agency should not be taken as simply the agency of a scientific discipline as separate from practice. Instead, I have emphasised that disciplinary agency denotes the *disciplined* agency of routine conceptual associations that structure the repetitive human performances in scientific practices (across multiple disciplinary contexts). This interpretation is drawn from Pickering's (1995b, 102, 110) descriptions of the 'disciplining of human agency' and his speculations on how the transmissions of disciplined performances can be deployed in diverse situations while also being mangled, along with the material and human components, within scientific practice. Interpreting disciplinary agency as the force of disciplined human performances within scientific practices (rather than the forces of disciplines) is also consistent with Pickering's focus on materially-mediated experimental practices.

My understanding of Pickering's notion of disciplinary agency shares similarities with Hasok Chang's (2014, 72–73) descriptions of how individual actions by human agents cohere together within systems of practice to become 'epistemic activities'. For Chang (2014, 73), calling something an *activity* highlights that the "routinized and repeated performance of an act [is carried out] according to a reasonably fixed set of rules governing… attempts to achieve the aim of the activity". Viewed in this way, epistemic activities can be seen to cohere within a given system of scientific practice by "coming together in an effective way towards the achievement of the aims of the system" (Chang 2014, 72). For Chang (2014, 73), it is "the aim of an activity that defines [this] coherence". In explaining this, Chang (2014, 74) provides a valuable distinction between two different kinds of aims: 1) those specific aims that are met through the inherent purpose of an activity; and 2) the more complex aims within which the activity is intended to contribute to various functions that are external to its inherent purpose. To meet these more complex aims coordination between various specific aims can go beyond the inherent purposes of each specific aim (Chang 2014, 74). This coordination occurs within a system of practice that pulls specific aims together (in more-or-less coherent ways) to achieve the complex aims (Chang 2014, 74).

Chang also shares Pickering's careful attention to the notion that human intentions meet resistance from multiple sources within scientific practice. For example, Chang (2015, 379) notes the "resistance that nature offers to out epistemic activities". In addition, Chang (2014, 71) highlights that human actions are constrained by their capabilities, limitations, and embodied knowledge: "by the expectations with which and within which we act". Combining the language of Edmund Husserl and Michael Polanyi, Chang (2014, 71) suggests that unrecognised expectations provide the 'horizon' of each moment to tacitly guide activities without articulating any explanation for why we act in such a way.

However, while Chang's account of scientific practice highlights the resistance that intentional human activities may meet in practice, the focus remains on the human-elements in these practices. Therefore, while Pickering's approach can be seen in agreement with that of Chang (if not vice versa), Pickering's approach offers an account that explicitly decentres the human-element in analyses of scientific practice. In doing so, Pickering's approach draws attention to the insights from studies of technoscientific practices.

It is within the context of technoscientific studies that the notion of disciplinary agency can be most readily located *along-side material agency*. In this way, Pickering's approach also aligns with others that emphasise those fields of experimental systems that can cohere around objects or research in ways that cross disciplinary boundaries. An example of this type of approach is Rouse's (1996, 128–30, 2015, 245) descriptions of experimental practices that integrate instrumentation, technical skill, and conceptual-articulation in ways that construct reproducible and transportable arrangements of a particular aspect of the world. Likewise, Rheinberger (2010b, 114, 2011, 315) describes how scientific knowledge is generated via the dynamic amalgamations of materially mediated research units that are not bound to the rigid social solidification of any specific discipline. In line with these approaches, Pickering (1982, 127, 1995b, 143–44, 2006a, 254) describes the agency of disciplined human performances as carried from the specifics of their development into new research contexts. Disciplinary agency can therefore be understood as the transportable forces of routine conceptual associations that – cohering around an object of research – can structure the repetitive human performance investigating this object across multiple research contexts.

The role that conceptual structures play in carrying along these disciplined performances within scientific practices can be further clarified through the resistance they provide to other elements within these mangled processes. It is in relation to this point that Pickering talks about disciplinary agency in ways that are analogous to material agency. Specifically, Pickering (1995b, 29, 70), describes conceptual structures as playing an analogous role in the human-disciplinary interactions of scientific practice to the role described for material instruments within human-material interactions.

The processes by which the intentions of human agents interact, through a resistance-accommodation dialectic with disciplinary agency, can be demonstrated by a brief outline of Pickering's (1995b, 115, 139–40) account of conceptual practice. This account takes a standard account of conceptual practice and positions it as one of the heterogeneous aspects of real-time scientific practice (Pickering 2006a, 274). As such, Pickering's approach rests upon two relatively uncontroversial understandings of science. Firstly, his account of conceptual practice aligns with others that describe conceptual extension as a process of modelling (e.g., Nersessian 2012).[53] In addition, and in line with one of the general themes that emerge from focusing on scientific practice, Pickering draws attention to the heterogeneous (material, conceptual, and human) elements that interact within scientific practices.[54]

Drawing these two points together Pickering's description of conceptual extension become one where humans accommodate the resistance of disciplinary agency (embodied in conceptual structures) much as they would accommodate the material resistance captured by machines. To start with, Pickering (1995, pp.115, 139) describes the modelling processes of conceptual extension as including three sequential phases within which the dialectic of resistance-accommodation plays out: a 'bridging' phase between base concepts and the tentative vector of cultural extension to be explored; a 'transcribing' phase between the old concept model and the new; and a 'filling' phase where the new model is filled-in without clear direction from the base model. During the 'free moves' of the 'bridging' and 'filling' phases, disciplinary agency is tentatively constrained by the discretionary choices made by human agents (Pickering, 1995: 139). Whereas the transcription phase is where human agency passively accommodates the resistance of the disciplinary agency as captured in institutionalised conceptual structures (Pickering, 1995: 115–117, 139–140). In the intermediary transcription phase, the human agent therefore makes 'forced moves' that carry the training and institutionalised disciplinary procedures (that provide established ways of

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[53] These modelling practices incorporate concepts as one of many resources so considering the role of scientific models is a larger-scale question than the one I am focusing on here.

[54] For example, see Chang's (2014, 68) discussion on how the heterogeneity of scientific practice has featured in the work of Kuhn, Rheinberger, and Hacking (among others).

linking material data with conceptual symbols) into the new conceptual structure (Pickering, 1995: 115–117).[55]

In this way, the alternating resistance-accommodation dialectic ensures that conceptual structures, as captured disciplinary agency, carry the 'free moves' of human agents along the unpredictable open-ended trajectories of real-time scientific practice (Pickering, 1995: 139). In these processes, new conceptual apparatuses (such as concepts or models for representing the structured associations between theories and data) are built by the resistance-accommodation dialectic between human agency (intentional actions) and disciplinary agency (the routinised practices embodied in existing conceptual structures) (Pickering 2006a, 254).

Described in this way, conceptual structures are clearly distinct from theory. This type of distinction is consistent with other accounts of concepts as elements of scientific practice that are distinct from theory. For example, Nersessian (1984) demonstrates that scientific concepts are formed and modified independently of theory. Taking a similar approach, Steinle (2010b, 36) argues that, in contrast to the extended systems of theories, concepts are not explanations in and of themselves (even though, as fundamental elements of thought, concepts are also necessarily used in explanations).

Positioned within the context of Pickering's (2006a, 253) broader account of scientific practice, new conceptual structures can be understood as modelled on existing conceptual structures just as new machines are modelled on old ones; both practices that can be orthogonal to theoretical development. Along the way, conceptual structures domesticate

[55] Note that, the separation of conceptual and material practice in these analyses is artificial. Human, disciplinary, and material forces in scientific practice all interact with each other (Pickering 2006a, 278). For example, if a physical form such as a mathematical formula is being developed, conceptual practice also includes resistance-accommodation dialectic between material agency (captured in the physical form) and both disciplinary agency (captured in the existing conceptual structures of the discipline) and human intention (Pickering 1995b, 144).

and embody the disciplinary agency of conceptual practice in the same way that material instruments such as machines capture and tame the agency of the material world (Pickering 1995b, 116–17). Therefore, although their formation is an open-ended and unpredictable process, these conceptual structures can nonetheless come to 'embody' the systematic and disciplined 'machine-like actions' of conceptual practices (Pickering 1995b, 115–16, 146).

In addition, just as the use of a machine is readily transported beyond the discipline within which it developed, capturing the routinised force of conceptual practice in a form that can be detached from the specific local conditions of production enables conceptual structures to become independent of theoretical practice (See, Pickering 1982, 127, 2006a, 254). That is, once formed, conceptual structures embody the force of the disciplinary agency that participated in their formation and can carry this force beyond an initial (e.g., disciplinary-specific) context and into other layers of scientific culture (Pickering 1995b, 143–44). In this way, conceptual structures can operate to carry the routines of disciplined human performances into, and out of, experiments.

To borrow Pickering's (2006a, 254) words, "conceptual structures… relate to disciplinary agency much as do machines to material agency". This suggests that, like machines, conceptual structures can actively contribute to experimentally generated knowledges. Indeed, Pickering (2006a, 254) argues that conceptual structures are required to capture and frame the material agency that a machine, in its turn, has captured. In this context, framing refers to the "delicate and open-ended process of reconfiguring the material culture of science in the pursuit of material performances that can be precisely aligned with conceptual structures" (Pickering 1995b, 97). It is through this process of 'framing' that the performances of the human-material interactions of experimental practice are able to pass through the levels of abstraction and conceptual multiplicity required to capture material agency as forms of theoretical and factual knowledge (Pickering 2006a, 278).

At this point, it is important to clarify that, although operating in analogous ways, the material agency captured by material instruments and the disciplinary agency captured by conceptual structures are not equivalent. Following Pickering's lead, I am treating the resistances that human agents meet when interacting with material instruments and conceptual structures as distinct yet inextricably linked.[56] Material instruments embody the forces of the material world by capturing particular effects that these forces produce on the world. This material agency can resist human intention – a resistance that *may* indicate something unknown about the otherness of the aspect of the world being investigated.

As detailed in Chapter One, determining whether material resistance indicates an artefact of the experimental setup or genuine otherness about the world requires an active choice to further investigate: it is through the numerous iterations of this 'dance of resistance and accommodation' that stable scientific knowledge is generated about aspects of the world. Conceptual structures, on the other hand, embody the persistence of disciplined human performances that capture the routine associations in ways that get carried along independently of human intention. This disciplinary agency can resist human intention by limiting the field of possibilities within which new knowledge about the world can be connected to the existing body of relevant knowledge.

However, while distinct, it can be difficult to determine whether the obstacles human agents meet within experimental practice indicate resistance from material forces and/or existing fields of knowledge. As such, the resistance-accommodation processes must incorporate the dynamics between human, material, and conceptual performances; each mangled though their adaptive responses to the actions of the others. As noted earlier but beyond the present scope, although contingent, it is important to appreciate that these

[56] Pickering does not explicitly make this distinction; I am extrapolating on his various descriptions of both material agency and disciplinary agency.

emergent process of interactive stabilisation (between human, material, and conceptual elements of scientific practice) can provide robust descriptions of objects/phenomena.

In this light, the conceptual elements of experimental practice can be understood as actively contributing, along with other elements, to the generation of scientific knowledge-claims; claims that have the potential of latching onto the world in a robust way that is contingent on this process. With this in mind, the various descriptions of conceptual structures that Pickering (1995b, 70, 115–17, 139) offers can be drawn together. In doing so, Pickering's descriptions of conceptual structures highlight the value of identifying structured conceptual associations that can both contribute to scientific knowledge (by embodying disciplined human performances in ways that resist human intention) while remaining open to change within the temporally emergent dynamics of scientific practice. With this established, my interpretation of Pickering's notion of conceptual structures can be productively compared with a range of other ways in which this term has been used.

2.2 Conceptual Structures as Participants in the Processes of Scientific Practices

The preceding interpretation of Pickering's notion of 'conceptual structures' is congruent with many other uses of the term. These similar uses all fall in the middle of a spectrum that stretches from notions about individual cognitive structures (e.g., Gardenfors 1997; Griffin 2004) to notions about the theoretical logic within which the intellectual and practical life of an age is confined (e.g., Barth 1974, 26–27). Excluding extremes such as these, the term conceptual structures can be taken as connoting those structures that govern the development and organisation of concept relations within a broader framework or system; relations that provide varying degrees of constraint on the uses of each concept within and across given communities. For example, descriptions of conceptual structures often emphasise different elements of the structured uses of concepts: including categorisation modules that are used to identify the referents of the terms in order tie together and distance concepts in terms of their similarity or dissimilarity (Andersen 2004, 2012); or the shared cognitive frames which set the constraints that link the attributes and values of concepts in ways that both enable and prevent the kinds of inferences that are acceptable at a given time (Barker 2011; U. Feest and Steinle 2012, 6). A particularly striking example can be found in Nersessian's (2008, 199–200) account of concept development:

> "A conceptual structure systematically organises concepts in relations with one another… [yet] is rich and complex and it is unlikely that a person or a community could have a holistic grasp of it and its implications".

In line with these approaches, the conceptual structures of interest are taken as dynamic element of shared practices – rather than an element of either individual cognition or over-arching social systems of thought. This can be clarified by considering Hanne Andersen's (2012, 274) description of conceptual structures as "a general sort of categorization module that divides objects into groups according to similarity and dissimilarity between… problem solutions". This description draws on Kuhn's analysis of instances of contrasting concepts to highlight how structural connections between concepts are routinely taken to imply ontological knowledge of regularities about the world (Andersen, Barker, and Chen 2006, 65). At the same time, this approach emphasises that there are multiple ways of representing the multivalued attributes integrated by structural connections (Barker, Chen, and Andersen 2003, 224; Andersen, Barker, and Chen 2006, 65–66).

This emphasis on the framing that integrates conceptual relations suggests that it is important to provide an account of how current knowledge of the world is inherited (through hierarchical principles of a stable conceptual structure) in ways that can respond to anomalous challenges to these principles. In relation not this, Andersen (2012, 274) describes how 'graded structures' are used by different members of the scientific community in ways that explain why some anomalies in the 'no-overlap rule' do not challenge the conceptual structure. In this way, and in contrast with Kuhn's assumption of a mutual independence of disciplines, Andersen (2012, 282) suggests that conceptual resources can be combined across disciplines, adopting structures and constraints from each discipline in the process.

Disciplinary movement of conceptual structures are also taken up by Pickering's (1982, 127) critical development of Kuhn's notion of exemplars already discussed. For example, Pickering suggests that conceptual structures – in becoming routinised – operate as the embodiment of the systematic machine-like actions of the disciplined patterns of human agency within which they formed. Routinised and detached from the local conditions, these conceptual structures are then carried into a variety of experimental practices (Pickering 1995b, 97, 2006a, 254). In this way, Pickering's view of conceptual structures converges with the body of work within science studies emphasising that scientific models and concepts can be used with variable autonomy from their role in theoretical representations (e.g., Arabatzis and Nersessian 2015; Rouse 2011b, 14).[57] In particular, rather than focusing on how the meaning of concepts are structured in relation to a theory, these notions of conceptual structures relate the development and use of conceptual associations to potentially contradicting theories within a broader governing framework of disciplined practices within interdisciplinary research.[58]

From my earlier description, Pickering's account of conceptual structures can be understood as consistent with those other uses of the term to highlight the application of

[57] Indeed, Joseph Rouse (1996, 176) noted that he and Pickering "argued independently [that] the relevant 'resistances' to the achievement and maintenance of epistemic alignments within scientific practice cannot be confined to either social or material categories in opposition to the other"

[58] It is in this way that Pickering's notion of conceptual structures can also be disentangled from superficially similar terms revolving around theories and concept-meaning.[58] There are numerous examples: 'explanatory structures' that consist of unified sets of articulated theories (Gaukroger 1978, 3); 'conceptual schemes' associated with the categories of meaning that organise our experience of the world (Alvarado 2008, 2; D. Davidson 1980, 183); and 'conceptual systems' that consist of hierarchical concept-meanings linked by rules (Thagard 1992, 30).

conceptual associations in practice rather than in the theoretical reference of concept meanings. Similarly, like the above notions of conceptual structures, Pickering's use of the term also highlights the forces by which the routines of disciplined human performances constrain human intentions within scientific practice. In addition, Pickering (1995b, 66 note 37, 2006a, 279) insists that the constraints that conceptual structures carry into experimental practice are as emergent as all the other aspects of scientific practice.

As noted earlier, Pickering (1995a, 67) illustrates this interactive notion of constraint by detailing the dance between human and material elements in scientific practice. For Pickering (1995b, 65–67, 1999, 168–69), constraints must be considered within the plane of practice; as an emerging form of resistance to the alignment *between* the human, material, and conceptual elements of scientific practice. This notion of emerging constraints differs from alternative accounts of scientific practice that focus on the notion of synchronic yet pre-existing constraints (that are located within social structures that are external to, yet control or explain, scientific practice).[59] Instead, as Theodore R. Schatzki (1999, 159) notes, Pickering's account of resistance-accommodation dialectics can be considered in line with more minimally construed notions of constraints, such as those that provide a field of possibilities.

Understood in this way, interactive constraints operate as a field of possibilities that delimit an indefinite array of sequences (Schatzki 1999, 159).[60] Put another way, the current arrangements of elements within the given practice facilitate the immediate pursuit of a given sequence of possibilities while precluding other possible sequences. In this way, any given element in these practices can operate as an interactive constraint on the field of possible

[59] For example, see debates on 'constraint' between Pickering and Galison (Baigrie 1995; Galison 1995; Pickering 1995a; Hacking 1995a; Vertesi 2015, 288; Zammito 2004).

[60] See Rouse (1996, 132) for a detailed philosophical account of scientific practice that draws on the notion of fields of possibility that are, in their own turn, remade.

sequences that can be immediately reached from the arrangement of social, material, and human elements in scientific practices that element participate in.

It is this focus on emergent practice that provides Pickering's notion of conceptual structures with a key point of difference from Kuhn's notion of paradigms. For example, Pickering (2001, 503) describes Kuhn's interest in paradigms as focusing on the conceptual superstructure (the disciplinary matrix) and individual and community 'mind-sets' (exemplars) without exploring the relationship between specific conceptual and material strata of science.[61] In comparison, for Pickering (1995b, 143), disciplinary agency is 'mangled' within "the very dialectics of resistance and accommodation [between material and human elements of experiment] to which it gives structure". As such, although embodying entrenched traditions of conceptual practice, these disciplined performances of human agency are frequently transformed though the processes of interactive stabilisation. Indeed, within the resistance-accommodation dynamics of scientific practice, human choices can make 'selective and tentative modifications' to the disciplined routines that structure the use of concepts (Pickering 1995b, 143). Therefore, rather than governing though unidirectional constraint, disciplinary agency provides humans with another resistance-accommodation dance partner within the dynamics that emerge between the heterogeneous elements contributing to scientific practices.

In addition, by tracing the trajectory whereby disciplinary agency 'dances' with human agents, conceptual structures can also be seen as open to being equally 'mangled' within experimental practice (Pickering 1995b, 115–17, 143). These trajectories highlight the temporally dynamic patterns within which conceptual structures can be understood in two interlocking ways: as the conceptual apparatuses that form to structure associations between

[61] For example, although discussing the constraints that a disciplinary matrix places on methodological practices and instrument use, Kuhn's (1970, 40–42) analysis remains unidirectional.

the theoretical and material elements of scientific practice; and as the embodiment of disciplinary procedures that structure the very associations that can form in this way.

Although the various features of conceptual structures are all mangled together in the temporal dynamics of practice, the force of the disciplined procedures they carry-along can be illustrated though an artificially chronological description of the role each feature provides. Firstly, the conceptual apparatuses that articulate the structured associations between material data and theoretical models are formed by the unpredictable dynamics of a resistance-accommodation dialectic between the goal of a scientist and the sedimented and routinised use of concepts already entrenched within the scientist's field of knowledge (Pickering 1995b, 115). Secondly, once in a form that can detach from their circumstances of production, these institutionalised conceptual structures act as the embodiment of the disciplinary agency involved in their formation (Pickering 1995b, 143–44). Thirdly, having carried the disciplinary agency from conceptual practice into experimental practice, the detached disciplinary agency (embodied as conceptual structures) continues to act alongside all the other elements of scientific practice within the decentred and temporally emergent 'mangling' – the unpredictable outcome of which can subsequently re-enter disciplinary conceptual practices to, ideally, continue the cycle and produce new associations in an open-ended dynamic process of knowledge production (Pickering 1995b, 115–16, 1143–44).

Many aspects of this account of the mangling of material, social, and conceptual aspects of scientific practice described by Pickering draw on insights that emerged within early twentieth-century historical accounts of scientific concepts. Indeed, Pickering (1995b, 119, 121) notes that descriptions of conceptual resistance can be found in the work of Fleck and Bachelard. For example, Fleck described the acquisition of knowledge as an iterative procedure – where, because phenomena have the capacity to resist, each iteration of our conceptions are contingent on the state of knowledge in that moment (Rheinberger 2005b, 21). In relation to this, Fleck (1979) proposed that the flux of scientific practices is structured by multiple, continually transforming thought-styles. These thought styles provide a way of explaining how scientific knowledge can provide 'undoubted facts' that are nonetheless contingent on the history of the collective thoughts constituting scientific practice (Fleck 1979, 97).

However, there are several points where Pickering parts ways with Fleck. The most obvious is that, compared to Fleck's focus on the collective (social) practices of science, Pickering concentrates on concepts in relation to the material contributions to scientific practice. In addition, while Fleck describes the resistance met through the rigid conceptual relations within a thought style, Pickering's work offers a way of analysing the more flexible disciplinary resistance that conceptual structures embody in ways that can outlast thought-styles. Furthermore, for Fleck (1979, 27), the resistance from concepts comes when they have fossilised within "structurally complete and closed systems" of complex relations within a given thought style in a way that "offers constant resistance to anything that contradicts it". In this view, the resistance from concepts occurs when, through the "enduring, rigid structures [*Gebilde*]" of a thought styles, they are used in a way that preserves certain systems of opinions within thought collectives (Fleck 1979, 28). In contrast, Pickering's approach highlights that there are structured ways of using concepts that extend across – yet are constantly mangled within – the dynamic interactions between the material, conceptual, and social elements of scientific practice.

A more direct foreshadowing of the material-conceptual-human mangle described by Pickering can be found in the work of Bachelard. For example, Bachelard famously described phenomena, instruments, objects, scientific spirit, concepts, and methods as joined with each other, all in a process of mutual instruction involving resistances and accommodations (Rheinberger 2005b, 320). Within these interactions, conceptual associations accrue to function in routine ways. For example, in Bachelard's account, concepts carry remnants of their past as implicit assumptions or conceptual and perceptive habits that can only be understood within the context of the various stages contributing to the historical development of a given concept (Gutting 1989, 17).

Building on the work of Bachelard, Canguilhem's work also prefigures Pickering's account by presenting a view of conceptual history as both temporally emergent and practice-oriented (Méthot 2013, 113; Rheinberger 2010a, 11).[62] Furthermore, Canguilhem is credited with making an important methodological step in analysing scientific practice by offering a distinction between theories and concepts (Gutting 2003, 52). Rather than concepts serving theory, theories are an explanatory product of scientific practice made possible by the conditions of the transformations of functional concepts in describing phenomenon within experimental practice (Rose 1998, 155; Gutting 2003, 53). By taking this approach, Canguilhem presents concepts as complex and dynamic 'laboratory actors' that operate to combine terms, definitions, and phenomena in ways that can interact with other devices (Schmidgen 2014, 234, 254).

Both Bachelard and Canguilhem position scientific concepts as historically contingent elements of practice that operate in structured concert with the material and human elements of scientific practice.[63] Interpreted in the light of these earlier insights, Pickering's approach can be taken to suggest that, in addition to re-configuring the modelling process of

[62] For example, see (Canguilhem 2008, 9, 43, 76).

[63] Although shifting away from this practice-focus, Michel Foucault built upon the work of both Bachelard and Canguilhem. Emphasising the importance of providing a descriptive analysis of the conditions of knowledge (savoir) through which a body of knowledge (connaissance) came to be, Foucault (1972, 35–36, 202–6, 210) sought to reveal the false unity of a stable discoverable object by exploring how the regularities and modifications of discursive practices give rise to particular scientific norms within which scientific objects, concepts, and theories emerge and are transformed. This has been an influential and fruitful approach. For example, see Arnold I. Davidson's (1996, 94) work on the tension between the conditions of emergence for the concept of 'perversion', and the attempts to ignore those conditions when using the concept.

conceptual practice in terms of the resistance-accommodation dialectic, there are dynamic roles for conceptual structures in experimental practice. Indeed, within the context of Pickering's broader account of the resistance-accommodation dialectics of scientific practice, conceptual structures can be understood as embodying the disciplined human performances to carry entrenched associations from conceptual practice into experimental practice (and back) during an open-ended development within the emergent dynamics of scientific practice. To do this, conceptual structures operate as an apparatus that captures disciplinary agency in a form that actively contributes to experimental practice.

One way of appreciating this active contribution is by considering Pickering's (2015, 126–27) metaphor of islands of articulated knowledge built from the alignment between material performances and conceptual structures. As mentioned in Chapter One, Pickering (2015, 126–27), argues that is it is through these alignments that islands of knowledge can form out of contingent practices to operate as reliable objective accounts of the real world. Positioned in relation to Pickering's earlier work, this suggests that the data that material instruments generate about a given object or type of phenomena is articulated as knowledge through an alignment with the stable concept used to investigate the object/phenomena. This suggestion provides a way of appreciating how, within the dynamic interactions of scientific practice, the momentary stability of conceptual structures can participate in generating the stable islands of scientific knowledge that experimental findings contribute to.

This island metaphor aligns with Pickering's analogy between conceptual structures and material instruments to highlight convergences between the STS literature on the role of nonhumans in experimental practice and the HPS literature on the dynamics of conceptual practice (each of which I detailed in Chapter One). In exploring these convergences further in the following section, I will position Pickering's notion of conceptual structures within the context of recent scholarship highlighting how concepts are used as tools for investigating specific epistemic goals.

2.3 The Structured Uses of Concepts as Tools for Investigating Epistemic Goals

Pickering extends an appreciation of the active role of material instruments in knowledge production to a consideration of conceptual structures as contributing to the knowledge generated in experimental practices. As detailed earlier, Pickering's descriptions of conceptual structures are broadly congruent with a range of other uses of the term. The additional element of interest in Pickering's descriptions is the interactions between conceptual and material elements of scientific practice. Focusing on this feature, my selective appropriation of Pickering's account of scientific practice seeks to highlight convergences between STS interest in nonhuman agency and the HPS interest in the contributions of concepts to experimental practice (each outlined in Chapter One).

To demonstrate this convergence, I will begin this section by examining how recent work within HPS provides a view of conceptual practice as dynamic temporal processes connected to concept use; a view that resonates with Pickering's 'mangled' view of scientific practice. As outlined in Chapter One, this recent interest in conceptual practice explicitly challenges the traditional view that scientific concepts are merely mental or linguistic representations of the outcomes of scientific practice. As such, these recent accounts of conceptual practice are readily distinguished from the wide range of more influential accounts of concepts as mental representations. For example, this approach is distinct from discourses in cognitive science that debate whether concepts operate as perceptual or amodal mental representations that are either invariable across individuals/uses or context-dependent (see: J. McCaffrey and Machery 2012; Bloch-Mullins 2015).[64] It is similarly distinct

[64] Although beyond the present scope, each side of these debates about modal/amodal concepts appear to draw on the same set of differing intuitions about the necessary or superfluous role of

from the philosophical discourse that continues the debates over inferential/atomic views of concepts; the relationship between definitions of concepts and the essence of scientific kinds; and the relevance of philosophical theories of concepts more broadly (J. McCaffrey and Machery 2012; Bloch 2012b; Malmgren et al. 2010).

In contrast to these two contexts, recent HPS accounts of conceptual practice highlight how the uses of scientific concepts extend beyond their roles within mental and linguistic representation. Renewed interest in the dynamics of conceptual practice within HPS has provided several distinct contributions that each focus on the role of concepts as used in scientific practice.

One reoccurring theme has been to position concepts as tools that are used in ways that enable scientific practice (Boon 2012, 220; U. Feest 2012; MacLeod 2012, 68; Steinle 2012, 105). Within this context, scientific concepts need not be 'accurate' to be useful and so should be assessed in terms of whether they are *appropriate* for a specified goal rather than limiting questions to that of accurately 'picking out' the intendent referent.[65] This view opens new avenues for examining scientific practices. One example mentioned earlier was Feest's (2010, 181–82) analogy between scientific concepts and data-generating instruments, such as microscopes and thermometers.[66] With this analogy, Feest (2010, 181–82) highlights that concepts can be used to measure whether a given phenomenon is present, or to explore "the very nature of a given phenomenon". In this way, the uses of concepts as tools can be understood as epistemically productive. Used as tools, concepts allow researchers to

mental imagery in abstract thought that, as I discuss in Chapter Four, dominated multiple 20th century debates over the concept of mental imagery.

[65] For more detail see *scientific concepts* in Appendix 1 (Annotated Glossary)..

[66] It is important to remember, as Boon (2012, 229) points out, that tool-like properties of a concept emerge through the addition and adaptation of existing empirical and theoretical knowledge, analogies, and other concepts in ways that categorise how the phenomena can be used.

intervene in a given domain of study even when there is only a vague or inaccurate conceptualisation of the phenomena available (U. Feest 2010, 183).[67]

In offering this analogy Feest (2010, 180–81) presents tools as devices that, whether physical or not, provide ways to do things in the world in ways that generate data and, therefore, contribute to scientific practice. As an analogy between concept-use and instrument-use (where each operate as tools that intervene in experimental practice), Feest's analogy is therefore distinct from Pickering's analogy between material instruments and conceptual structures (where each embody nonhuman agency in a way that can resist human intention).

For Pickering (1995b, 158–59) tools are human-nonhuman composites (such as machines that require a human operator) and distinct from autonomous machines. At the same time, Pickering (1995b, 158) stresses that the "need for a skilled operator to channel their agency in desired directions... does not undercut [his] idea that material machines capture nonhuman agency". In this way, human-machine couples can – like autonomous machines – embody material agency in a way that resists human intentions. As such, while Pickering assumes a distinction between tools and machines, and focuses on the latter, his approach nonetheless allows an interpretation of both tools and machines as embodying material agency.[68] Even so, Pickering's description of the use of tools (as human/nonhuman couples) – as able to resist human intention in the same way as (autonomous) machines – is specific to material tools. As such, Pickering's analogy between material instruments and

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67 An important point given that, for Feest (2010, 183), the only access we have to the objects and phenomena that exist in reality (independently of us) is through our potentially inaccurate conceptualisations of them.

68 Although beyond the present scope, my interpretation of Pickering here could be productively positioned in relation to Canguilhem's view that both tools and machines operate as an extension of living force where life does not need to be human life (Hacking 1998a, 207).

conceptual structures focuses on their role in the 'machine-like' routine operations that contribute to scientific practice.

At this first glance, Feest's analogy between the use of concepts as tools and the use of material instruments as tools has little in common with Pickering's descriptions of tools as human/nonhuman couples. However, these two analogies each emphasise different yet complementary elements of the way that the concepts are used as tools that are structure for investigating specific epistemic goals; *structured uses* that can actively contribute to experimentally generated knowledges. On the one hand, Pickering's analogy highlights how nonhuman agency – whether the material agency captured by the actions of machines or the disciplined routines of entrenched conceptual associations (disciplinary agency) embodied by conceptual structures – can modify scientific practice. This analogy with machines highlights the value of analysing how other types of resistance to human intention within experimental practice might actively contribute to experimentally generated knowledge-claims.

While also emphasising the open-ended dynamics of experimental practice, Feest's analogy provides a different insight. There is no mention of either material agency or the disciplined routines of conceptual practice. Instead, Feest (2010, 181) highlights that concepts themselves can be understood as tools that generate knowledge by means of generating data in a similar way to the data-generating capabilities of material instruments. In relation to this, Feest (2010, 182, 188) describes two specific data-generating functions that concepts can play. The first function is as a tool for identifying if and, if so, to what extent a given phenomenon is present in an experimental condition. The second function is as a tool for intervening in the domain of study to explore the very nature of the type of phenomena of interest. Both functions rely on the ability of the tool (the scientific concept) to successfully individuate the type of phenomena of interest by delineating the class of phenomenon of interest from other types of phenomena within an available body of knowledge (U. Feest 2010, 173).

Despite their differences, this intersection between Pickering and Feest's respective analogies is of value. When taken together, the analogies offered by Feest and Pickering suggest that concepts (used as goal-directed tools) and conceptual structures (which operate in a more autonomous machine-like way) can both be argued to contribute to scientific practice in ways that are analogous to aspects of the contributions of material instruments (tools and machines). In this way, Feest and Pickering both draw attention to the importance of recognising the role that the conceptualisation of types of phenomena play in generating the knowledges through which we interact with phenomena that exist independently of us.

Taken together, these analogies suggest that conceptual tools fail to fall neatly into either the human or nonhuman elements of scientific practice. Instead, the structures uses of tools function as 'quasi-others', to borrow Ihde's (1979, 40) description of technologies as neither 'mere' tools than humans control not rarefied autonomous entities . One way to understand this quasi-otherness is by viewing conceptual tools as human/nonhuman couplings that – when structured by routine performances that emerge within the material, human, and conceptual interactions within experimental practice – can act in analogous ways to routinised material instruments (whether these are routine uses of mundane tools or the routines of semi-autonomous machines). In this way, the intersection between these two analogies highlights that the use of conceptual tools can embody the disciplined routines of conceptual associations to provide paradigmatic conditions within which data is generated in ways that can resist human intention.

This intersection between Feest and Pickering's analogies can be built upon to suggest that, used as tools that are so routinely relied upon the appropriateness of a conceptual tool can go unquestioned. Unquestioned uses of these concepts as tools thus function as elements of the structured machine-like routine processes of an entrenched set of conceptual practices. This understanding suggests that, as with the machine-like roles of conceptual structures, the uses of concepts as tools involve human/nonhuman interactions can contribute to experiments in ways that are not entirely in the control of human intention.

Complementing Feest and Pickering's analogies, Klein (2001, 296) describes how the skilled manipulation of rarefied sign systems (such as the Berzelian chemical formulas) can operate in a similar way to the skilled use of laboratory instruments to produce new knowledge. The use of these paper tools can become routine – used as reliable instruments rather than as object of research, tools both embody human goals and react back to shape those goals (U. Klein 2001, 296–97). Of course, in contrast to conceptual tools, paper tools are visible and manoeuvrable *material* devices (U. Klein 2001, 293). However, conceptual tools and paper tools are similar in other ways: neither are used to interact physically with the object under investigation, yet both go beyond merely representing the outcomes of scientific practice; producing new knowledge through their development and use.

Similarly, alluding to Pickering's notion of disciplinary agency, Régis Catinaud and Frédéric Wieber (2014, 157–58) argue that the role of theoretical artefacts within scientific practice need to be understood within the consistent practices that constitute the agency entrenched within the community using these tools. I am interested in the uses of incorporeal tools for intervening in scientific practice (rather than as representations for scientific knowledge). As such, a detailed consideration of how material representational tools can also actively contribute to experimental practice is beyond the present scope. However, recognising that this dialectic between tool-use and community goals applies equally to the use of concepts as tools raises a question: how exactly are concepts used in ways that extend beyond their representational roles in scientific practice?

Exploring this question, Feest (2012) describes the role of operational definitions as ways of articulating the paradigmatic conditions for applying a given concept in practice.[69] In relation to this, Feest (2012, 178) clarifies that, rather than exhausting the meaning of the defined concept, operational definitions make empirical presuppositions about the phenomena purported in the extension of the concept. These empirical presuppositions specify the paradigmatic conditions for the application of the concept in ways that allow the concept to be used as a data-generating tool (U. Feest 2012, 178). Feest's approach has been developed by Bloch (2012a, 192) to suggest that it is through the articulation provided by operational definitions that concepts can function as preliminary articulations that condense and integrate scientific knowledge in ways that allow for the isolation of instances of a given phenomenon. In addition, Feest (2016) argues that the roles of operational definitions in experimental practice extend beyond the analysis and interpretation of data; providing the tacit knowledge (both material and conceptual) that contribute to the very design of the experiments producing this data.

This discussion of the use of a concept's operational definitions to investigate instances of phenomena partially resembles Hans-Jörg Rheinberger's (1997) account of epistemic things. For Rheinberger (2005a, 407) an epistemic thing is a material object of enquiry that is still opaque. This opacity of unconfirmed scientific objects means that productive contributions to experimental processes emerge from the blurred distinctions between an epistemic thing and its concept (Rheinberger 2010a, 154). Given these blurred distinctions, the phenomena around which the research forms can lack a rigid definition (Rheinberger 2000b, 221, 225). As such, it is these loose definitions of preliminary concepts that provide

[69] I am adopting Feest's use of *operational definition* here - see Appendix 1 (Annotated Glossary).

space for the diversity of meanings by which experimental research can "reach out into the realm of the unknown" (Rheinberger 2000b, 223).

However, as Feest (2010, 184) argues, because Rheinberger does not distinguish between the concepts of objects and the objects themselves, his approach obscures the roles that the uses of specific concepts as tools have in the empirical generation of knowledge. In contrast, while also in partial echo of Rheinberger, Theodore Arabatzis joins Feest and Bloch in revealing the active roles of concepts in experimental practice. For example, Arabatzis (2005, 3) describes how the conceptual representations of theoretical entities (as constructions from experimental data) are "active [non-intentional] agents that participate in the development of scientific knowledge". More recently, Arabatzis (2012, 158) has also suggested that, when used to provide explanations for previously established facts, the meaning and reference of hidden-entity concepts can only be understood by examining their theory-independent uses in experimental practice. Therefore, like Rheinberger, Arabatzis (2012, 161) argues that scientists are often able to agree about the experimentally determined properties of a hidden entity even whilst disagreeing about how to theoretically account for its relevance. However, in addition to this, Arabatzis (2012, 155) also examines how the trans-theoretical use of concepts mean that they are both shaped by experimental practice and frame experimental findings.

Arabatzis' focus on the bidirectional dynamics between concepts and other elements of scientific practice parallel's Pickering's argument for the dynamic role of conceptual structure framing material agency (while also being 'mangled' in the process described earlier). A congruent point can also be found in Steinle's careful tracings of the changing work that scientists expect of a concept through time. In taking this approach, Steinle (2012, 106) emphasises that investigations of the use of concepts in the development of goals can be independent from questions about what object a concept references. In addition, Steinle

(2012, 107) also emphasises that the usefulness of a concept needs to be analysed in terms of the function that it plays in research activity towards a specific epistemic goal. Therefore, whereas Pickering focuses on how conceptual structures *interact* with other elements of scientific practice, Steinle highlights that the routine actions of using concepts as tools can be understood in relation to what these tools are used *for*.

One way to understand concepts as used for specific purposes is to return to the notion of epistemic activities discussed earlier. For Chang (2014, 72–74) epistemic activities involve both simple and complex aims – the latter drawing the former together coherently in ways that contribute to achieving the aims of the system of practice. Considering the roles of concepts within these epistemic activities draws direct attention to the way that complex aims – such as the epistemic goal of explaining the regularities of a type of phenomenon – provides coherence between the diverse uses of a given concept for pursuing simple aims (or specific goals) in scientific practice.

Others have also drawn attention to the uses of concepts for pursuing goals (among other things). For example, MacLeod (2012, 68–69) proposes that one of the central epistemic attributes of a concept is the goal relevance that allows it to be used to pursue specific epistemic goals. For MacLeod (2012, 68–69) epistemic attributes are "particular parcels of information attributed by a concept to a referent". Thought of in this way, there are a range of epistemic attributes that allow a concept to be used in different ways: to pursue specific epistemic goals; to design research methods; to provide a provisional representation of the object/phenomena of research; and to contribute to theory-polyvalent interpretations of experimental data (MacLeod 2012, 68–69). As part of this, and in line with the accounts of concept-use more broadly, MacLeod (2012, 47) argues that the role of representing aspects of the world is only one of several functions of concepts. More specifically, for MacLeod (2012, 68–69), the epistemic attributes of a concept are both independent of a particular representation of the referent and central to the use of the concept in identifying and investigating the referent.

Building on this, MacLeod (2012, 68–69) argues that concepts can operate as "epistemic tools, structured around attributes, from which applications are developed and with respect to which representations take shape". Linking this back to the earlier discussion of concepts as tools, MacLeod (2012, 69) notes that epistemic features contribute to operational definitions yet "cannot be identified with their part in any particular operational definition".

Furthermore, in addition to examining what conceptual tools are used for, MacLeod draws attention to the relationship between the use of tools for investigating specific epistemic goals and the structures that provide the stability for these uses within the mangled dynamics of scientific practice. Firstly, MacLeod describes how the uses of concepts are structured around their epistemic attributes. Secondly, the roles of these structures within the open-ended dynamics of conceptual change are highlighted. For example, it is within the structure provided by a concept's attributes that scientists can confidently use them as stable tools for sustaining open investigative activity towards specific epistemic goals – within which "variable descriptions and representations are an inevitable part of the process" (MacLeod 2012, 70). As such, the central epistemic attributes of a given concepts provide structured ways of using that concept – structures which underwrite the stability of a concept during its open-ended use in experimental research (MacLeod 2012, 57, 68).

The value of analysing the structured use of a concept for pursuing a specific epistemic goal is also emphasised by the methodological approach proposed by Brigandt. This proposal focuses on analysing the various uses of theoretical concepts; specifically, those concepts where the rational for using the concept is to pursue a specific set of epistemic goals within a given scientific community (Brigandt 2010, 23). When analysing such concept uses, Brigandt (2010, 21) has proposed that the referential and inferential components of theoretical concepts need to be understood in relation to an additional component: "the epistemic goal pursued by the concept's use". Of these three components, the referential role of concepts is the most commonly recognised – it describes the object/phenomenon to which the concept refers. Therefore, Brigandt (2012, 77) offers an uncontroversial description of the referential component of concept use as the assumed referent associated with the use of that concept. In relation to this, the inferential role of a concept relates to *how* the concept is used (Brigandt 2012, 79). For Brigandt (2012, 78), how a concept is used (its inferential role) embodies the conceptual relationships that support the referential use of the concept – for example, relationships between the definition of the concept, any inferences supported by a concept, and the explanations the concept makes possible. Adding to these, Brigandt (2012, 78) describes a third component of concept-use: the use of concepts *for* pursuing epistemic goals.

Having made this distinction, Brigandt (2012, 99) focuses on examining how specific epistemic aims are embodied by the use of concepts (their inferential role) in pursuit of epistemic goals in ways that can influence the dynamics of scientific practice. Within this context, epistemic aims/goals operate on a different dimension from scientific beliefs (Brigandt 2012, 73). Rather than being a belief about our representations of the world, the epistemic aim of a concept is an example of the values ascribed to the intended outcome sought by the use of that concept for pursuing a specific epistemic goal (Brigandt 2012, 78). Given this, when the epistemic goal pursued by the use of a specific concept is stable, this goal sets the standards within which changes to the referential and/or inferential component contents of a concept are epistemically warranted (Brigandt 2010, 24).

Brigandt's description of the epistemic goals of concepts in relation to their more recognised components (i.e., their referential and inferential roles) is reminiscent of the view of concepts attributed to Canguilhem. For Canguilhem, concepts are dynamic entities that comprise the phenomenon, the denomination (term) for the phenomenon, and a definition that provides an explanatory link between the term and the phenomenon (Schmidgen 2014, 245–55). Within this context, the functions of concepts are considered to be grounded in a set of experimental practices which are themselves embedded in the wider social context (Canguilhem 2008, 9, 43, 76; Méthot 2013, 121). Likewise, Brigandt's approach helps to clarify how the epistemic aims embodied by the uses of a concept in investigative practice can operate in a dynamic relationship with the associations that the concept's inferential role embodies and the referential use that these associations support.

In addition, Brigandt's approach also echoes the view of concepts attributed to Bachelard. Firstly, Brigandt's description of the epistemic goal of concepts echoes Bachelard's argument that the functional role of concepts is to define the object towards which scientific investigation is directed (Tiles 1984, 183). This argument of Bachelard's also prefigures Feest's (2010, 173) description of concepts individuating a type of phenomena for further investigation by delineating the class of phenomenon of interest from other types of phenomena within an available body of knowledge (discussed in Chapter One). In addition, Bachelard makes the further point that the functional roles of concepts are only specifiable against the structured epistemological fields that constitutes the possibilities of posited object (Tiles 1984, 183). A concept's conditions of application are incorporated into its meaning – deforming it in the accommodation of new experimental proofs (Rheinberger 2010a, 34). Given this, Bachelard argued that it is only by examining the route which led to the dynamic and 'public life' of current concepts that the historical accretions entrenched in these terms can be realised (Tiles 1984, 157–59). This brings us back to Brigandt's argument that, given that the three components of concepts are dynamically variable in relation to each other, identifying the inferential role of concepts offers a way to specify the field of knowledge within which a concept is used for pursuing a given epistemic goal.

Contextualised in this way, Brigandt's approach can help to build on Pickering's description of conceptual practice mentioned earlier. For example, take Brigandt's (2012, 78) argument that an epistemic goal is embodied in the particular use of a concept in ways that sets the standards for investigative aims. This argument is congruent with Pickering's (1995b, 29, 115–16, 146) account of conceptual structures as the structured associations that form to align, and translate between, multiple elements of scientific practice. This convergence highlights how these structured associations provide the expectations that govern the epistemic aims embodied when using a concept as a tool for investigating a specific epistemic goal.

Furthermore, as mentioned earlier, Pickering's notion of disciplinary agency also converges with descriptions of epistemic activities that cohere within systems of practice provided by Chang (2014, 71–73). Recalling this convergence now, I seek to reiterate the point that individual human actions cohere to structure the horizon of expectations in each moment – tacitly guiding activities without articulating any explanation for why we act in such a way. Drawn together, these approaches suggest that the routines embodied in the structured use of a concept for pursuing an epistemic goal contribute to its stability in the emergent experimental practices.

Considering the coherence of individual activities within the disciplined structures of systems of conceptual practice draws the discussion back to the importance of appreciating the historical context within which these structured uses of concepts emerged. As Steinle (2012, 107, 123) points out, a bidirectional relationship between the development of a concept and the goals the concept is used to pursue can be revealed by focusing on the functions that concepts exert – on the work that concepts do or allow to be done within a given context. To provide an account of the dynamic history of a given concept, Steinle (2012, 123) has argued that it must include the goals that both shaped the concept and accommodate the successes and failures of that concept in turn. These bidirectional processes call to mind Pickering's dance of resistance and accommodation between human intentions (goals) and the resistance of disciplined human performances embodied in conceptual structures. For example, Steinle (2010b, 38) describes the "processes in the formation of empirical concepts [as] shaped by heterogeneous aspects – those of creativity, of choice and decisions taken – but also those of empirical input which are not free to be disposed of but have to be taken as is." However, rather than focusing on conceptual *formation*, I am interested in how these bidirectional interactions between concepts and goals are relevant when momentarily stable concepts are used in experimental practices.

In relation to this, I want to revisit Pickering's metaphor of the material-conceptual alignments as a process that can form islands of momentarily stable knowledge. This island-metaphor dovetails neatly with the notion that conceptual *sedimentation* can build-up overtime to provide the unexamined structure underlying scientific knowledge. For example, Steinle (2010a, 200) adapts Husserl's notion of sedimentation to explore how experimental concepts that emerged in a specific context latter came to appear as solidified and stable 'natural' categories (if not as facts).[70] In describing the sedimentation of concepts, Steinle (2010a, 213) is – like Pickering – careful to emphasise that the result is not immutable; describing it as less like sandstone and more like a coral reef, where the living and dead coexist. During this sedimentation process, the usefulness of a concept is proved in relation to certain historically contingent goals rather than questions of truth (Steinle 2010a, 206). However, once a concept has proved useful for a specific goal, within a specific context, sediment builds up until the concept is able to be used without any explicit awareness of the historically situated

[70] I have drawn on the analogies of sedimentation here as it has been used previously in relation to concepts; similar points have been made about the value of opening-up *black-boxes* (of various scales) within STS; especially those obscuring the social and material aspects of scientific practice.

usefulness. At the same time, Steinle (2010a, 213) also emphasises that sedimented concepts operate as a base for unpredictable development within new local sites of practice; a point reminiscent of Pickering's emphasis on the emergent heterogeneous dynamics of scientific practices.

Drawing these various points of intersections together, Pickering's notion of conceptual structures can be developed in new directions. Firstly, these converging accounts of conceptual practice highlights that one of the ways that conceptual structures contribute to scientific knowledge is through the structured uses of concepts as tools for investigating specific epistemic goals in experimental practice. Secondly, these converging accounts of conceptual practice emphasise the value of examining the historical context for current concept-use. This historical context might help to identify the bodies of knowledge providing the sediment within which certain associations came to be attributed to specific concepts. Thirdly, this intersection between STS and HPS offers a productive way of identifying some of the unintended contributions that the structured uses of specific concepts may have made to the generation of experimental knowledge. With these three points in mind, analysing the uses of concepts *as tools structured for investigating specific epistemic goals* offers a valuable analytic approach for examining localised experimental practices.

As mentioned, the rest of this thesis considers the value of this analytic approach for examining a concrete case. This case is the uses of two scientific concepts – mental imagery and hallucinations – for investigating the *neuroanatomical correlates* of distinct types of phenomena in neuroimaging experiments. In the following two chapters, I will introduce the concepts of mental imagery and hallucinations; examining how their once explicit interdependence continue to structure the independent uses of these conceptual tools in neuroimaging experiments.[71] Following that, I will devote three chapters to examining the relevance of the structured ways in which concepts are used as tools for investigating specific epistemic goals to the current uses of these two concepts within documented neuroimaging experiment. Drawing these approaches together in Chapter Eight, I will position the current independent uses of these two concepts in relation to the interdependent associations that weave through their respective histories. Examining these interdependent connections, I will argue that each of these concepts has been *structured* in relation to the other such that it can be *used for* investigating specific epistemic goals. Building on this argument, I will propose that the *structured uses* of these conceptual tools can contribute to experimentally generated knowledges in ways that are analogous, yet not equivalent, to the active contributions of material instruments.

[71] While I will be focusing on the role of concept as used in neuroimaging experiments, it is important to note the materiality of fMRI techniques also operate as participants within the experimental practice. For some detailed examples of the materiality of knowledge generating practices more generally, see Rheinberger's (2000a) biography of sub-atomic particle traces and Deborah Nicholson's (2003) history of ultrasound techniques in Scottish obstetrics.

3 Concepts as Used for Investigating Sensory-like Mental Phenomena

Sensory-like mental phenomena (SLMP) occur in the absence of relevant perceptual stimuli yet share certain *phenomenal properties* with one or more modalities of sensory perception.[72] Put simply, these SLMP are described 'as if' experiencing perception: to varying degrees as if 'hearing', 'seeing', 'tasting', 'touching', and/or otherwise 'feeling' something in the absence of the relevant sound, sight, taste, texture, and/or other perceptual stimuli. As an analytic category, SLMP provides a way of comparing different conceptualisations of quasi-perceptions. I will focus on two such concepts: the concept of *mental imagery* (predominantly used when investigating ordinary SLMP); and the concept of *hallucinations* (which provides the dominant concept for investigating clinically-relevant experiences of abnormal SLMP).[73]

As detailed in Chapter Two, concepts individuate a type of phenomena in ways that enable the further study of that phenomena in relation to a specific goal. This process of individuation involves condensing and integrating the available body of knowledge to articulate the causally-fundamental characteristics that delineate it from other types of phenomena for a specific purpose. Using the concepts of mental imagery and hallucinations, specific types of SLMP have been individuated for specific purposes of further investigation. For example, mental imagery is used in neuroimaging experiments investigating the functions of ordinary SLMP within neurocognition. Meanwhile, the concept of hallucinations is used in most neuroimaging experiments that investigate the pathology of dysfunctional experiences of SLMP. In each case, the specific type of SLMP of interest is associated – directly or indirectly – with a range of typical characteristics. These typical characteristics are

[72] This notion of *SLMP* is distinct from, yet parallels, Pearson and Westbrook's (2015) notion of *phantom perceptions* – see Appendix 1 (Annotated Glossary).

[73] Examining the range of other concepts used for *SLMP* is beyond the present scope, further examples have been included in Appendix 1 (Annotated Glossary).

taken to be representative of a specific type of SLMP; justifying the delineation between those SLMP that resemble perception (mental imagery), and those SLMP that have a compelling sense of perception (hallucinations), so that specific SLMP-neuroanatomical-correlates of either can be investigated in pursuit of unrelated goals (understanding SLMP in relation to either functional or dysfunctional neurocognition respectively).[74]

The concepts of mental imagery and hallucinations are each routinely used independently of the other.[75] This suggests that these two concepts are each taken to successfully delineate between functional and dysfunctional classes of SLMP for experimentally investigating the neurophysiological mechanisms underlying the role of SLMP in neurocognitive processes.[76] With this in mind, after introducing the concepts of mental imagery and hallucinations in turn, this chapter will focus on examining how experiences of ordinary SLMP conceptualised as mental imagery are characterised as distinct from those clinically-relevant SLMP conceptualised as hallucinations (and vice versa) for their respective uses in neuroimaging experiments.

This examination will not attempt to resolve questions of whether these concepts refer to discrete types of SLMP. Instead, I will examine the *uses* of the concepts of mental imagery and hallucinations for desirable and undesirable SLMP when differentiating between ordinary and pathological experiences of SLMP (for investigations into functional and dysfunctional neurocognitive processes respectively). In doing so, I will highlight that there is an ambiguity in the way ordinary and abnormal experiences of SLMP are characterised. As

[74] See, *SLMP-neuroanatomical-correlates* in Appendix 1 (Annotated Glossary).

[75] For an example of each, see: (D'Esposito et al. 1997; Frith and Dolan 1996).

[76] See Appendix 1 (Annotated Glossary) for the variability of the term *mechanism*. Also note that there are also experiments not aimed at identifying the mechanisms of SLMP – uses that still need to be examined. For some research into non-mechanist investigations within scientific practices, see (Colaço et al. 2015).

part of this I will demonstrate that 'typical' characterisations are neither necessary nor sufficient for explaining the independent uses of these mental imagery and hallucinations in neuroimaging experiments that investigate the role of SLMP in neurocognitive function and dysfunction respectively.[77] This ambiguity draws attention to the historical interdependence of the concepts of mental imagery and hallucinations. This historical interdependence will be examined in more detail in the following chapter. For now, it is important to introduce how the concepts of mental imagery and hallucinations are each used for investigating functional or dysfunctional experiences of SLMP respectively.

3.1 Mental Imagery

Mental images resemble the sensations of perception yet occur in the absence of the appropriate perceptual stimuli.[78] These images can provide mental reproductions of perceptual information (*memory-imagery*); allow for the combination, modification, and construction of perceptual information in novel ways (*imagination-imagery*); or contribute to both the reproduction and construction of perceptual information for other cognitive functions (e.g., Dumville 1931, 85; Stephen M. Kosslyn, Ganis, and Thompson 2010, 3; Roeckelein 2004, 12–24; N. J. Thomas 2006; Andrade et al. 2014). As such, the quasi-perceptual experiences of mental imagery are closely associated with the faculties of imagination, memory, perception, and conscious thought (N. J. Thomas 2006, 1). For example, Joel Pearson and colleagues (2015, 590) describe mental imagery as the

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[77] I will only be considering neuroimaging experiments. For a review experimental approaches for investigating mental imagery more broadly, see (Ganis and Schendan 2013). For an overview of neuroscientific investigations of hallucinations more broadly, see (Jardri et al. 2013).

[78] In this thesis, mental imagery (and related terms) indicates those conscious endogenous experiences of the waking state (in any sensory modality) that fall under this core definition. For an outline of broader applications of the term imagery, see (Lawson and Lacey 2013, 244; Roeckelein 2004, 68–69).

"representations and the accompanying experience of sensory information without a direct external stimulus… leading one to re-experience a version of the original stimuli or some novel combination of stimuli".

This notion that mental imagery 'resembles perception' is often illustrated though an introspective exercise. So, think about relaxing on the beach and describe what you think about. Then, describe *how* you experienced these thoughts about the beach. For some people, thinking involves recalling or anticipating related perceptual experiences in one or more sensory modality. For example, thinking about the beach might invoke mental imagery: sensations experienced, to varying degrees, 'as if' hearing the waves crashing, seeing the sparkling blue water, feeling the sand squish underfoot, and/or smelling the salty air. You may experience images in multiple sensory modalities or you may experience one or another alone, such as 'seeing' the water without 'hearing' anything at all (or vice versa). It is also possible that you thought about a beach without relying on any imagery at all. If this latter is the case, this introspective exercise may do little to illustrate the *experience* of mental imagery.

Regardless of what you experienced, you are likely in good company. Imagery questionnaires reflect a diverse range of thinking experiences: from reports of imagery experienced 'as if' perceived in all modalities, to reports that imagery is not experienced in any modality, and a range of others combinations besides (Andrade et al. 2014; Betts 1909; Faw 1997, 2009; Hubbard 2013a). For example, F.C. French (1902, 51) noted that 26% of subjects could not "recall the voice of the person [visually] imaged" despite easily recognising that voice when actually heard. There is also individual variability in the degree of similarity between a given experience of mental imagery (while thinking about being at a beach) and the actual perceptual sensation (of *being* at the beach) in any given modality. For instance, French (1902, 50) reported that the difference between an image and perception was 'imperceptible' for twenty-one subjects, while for five subjects "the mental picture… [was]

more vivid, stronger, or in some way superior to the real perception". Therefore, regardless of whether you experience these SLMP or not, these studies should help to show that mental imagery operates as a concept for experiencing SLMP that is valued by some people as part of their everyday thoughts. Indeed, for those who experience imagery, it can be a crucial part of their thinking processes. A classic example of the value of imagery are the reports that William Blake brought complete and fully formed imaginations before his mind's eye from which he then reproduced each detail on the workbench (Paivio 1983, 4). Likewise, offering a first-person account, Edward Titchener (1909a, 8) describes presenting lectures by relying on a 'written' table of contents visible in his 'mind's eye' and occasionally 'hearing' his own voice 'speaking just ahead' of him.

Determining the range of individual variability in mental imagery is difficult (see Chapter Four). One ongoing difficulty relates to disentangling the role of social desirability in measuring mental imagery (K. White, Sheehan, and Ashton 1977, 154–57). For example, high social desirability may play a role in inflating the prevalence of vivid visual imagery (McKelvie 1995; Reisberg, Pearson, and Kosslyn 2003, 157). Meanwhile, social desirability may have had the opposite impact when it comes to auditory imagery. For example, it has been suggested that auditory imagery is under-reported due to the stigma attached to the experience of auditory hallucinations in relation to psychosis (Hubbard 2013b, 240).

Therefore, putting aside the difficulties of measuring individual differences, it is the middle range of those more frequently reported experiences that have been taken as characteristic of ordinary experiences of SLMP. It is these reported 'abilities' of mental imagery that are typically taken as conforming to a Gaussian distribution (Roeckelein 2004, 160). Along the way, the tail ends of this distribution are often neatly smoothed over, if not forgotten.[79] All 'healthy' subjects are expected to experience mental imagery (especially in the visual modality): either as fleeting sensory-like accompaniments to their thoughts, or as tangible sensory-based thoughts that can be manipulated at will.

Given this smoothing, experiences of mental imagery are typically considered to be a "familiar aspect of most people's every day experiences" (N. J. T. Thomas 2014b). Taking this even further, all experiences of mental imagery have been proposed to have the general and *essential* function of simulating sensations (Moulton and Kosslyn 2009, 1274). For instance, Armelle Viard *et al.,* (2011, 2) introduced their neuroimaging study of 'mental time travel' by explaining that "Both past and future event constructions are strongly dependent on visual mental imagery". Likewise, Rebecca Keogh *et al.,* (2016) began their abstract with the statement that "Mental imagery provides an essential simulation tool for remembering the past and planning the future, and its strength affects both cognition and mental health".

Indeed, some cognitive scientists have even argued that the conscious use of a concept (say of a beach) *necessarily* involves the reproduction or simulation of the relevant perceptual information (such as the sound of the waves or the colour of the ocean).[80] The strong version of this view – that all forms of cognition require conscious mental simulations of perceptual information – is uncommon within the neuroimaging literature.[81] However, the weaker view – that *some* cognitive processes necessarily require conscious mental imagery – is frequently taken for granted. The uses of the concept of mental imagery for investigating specific neurocognitive functions often rely on the assumption that certain forms of memory require

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[79] The erasure of individual differences such as these have contributed to the turbulent historical disputes over the role of imagery in thought – some which will be detailed in following chapter. Also see: (Reisberg, Pearson, and Kosslyn 2003).

[80] For a review of this argument in relation to the 'embodied' theory of concepts, see (Bloch-Mullins 2015, 945)

[81] The 'strong-view' still features in 'neo-empiricist' accounts of concepts as perceptual representations. Philosophical debates around this view of concepts have been examined elsewhere, see: (J. McCaffrey and Machery 2012, 270–73; Bloch-Mullins 2015, 944–49).

mental imagery. For example, 'mental comparison tasks' are common within the imagery-research literature; even though, as David Pearson and colleagues (2013, 12) note, there "can be ambiguity in establishing whether task performance is based on inspecting mental imagery or instead abstract knowledge of the items compared".

Individual variability in thinking is routinely obscured by experiments that investigate ordinary experiences of mental imagery as a uniform element of (all) human thought. Despite some notable exceptions, individual variability in thought has been positioned as peripheral to scientific interest in experiences of imagery and, at times, ignored entirely.[82] Reinforcing this practice of obscuring individual variability is our tendency to each assume that everyone experiences thinking in the same way (i.e. the way that we do). People who rely strongly on multi-modal imagery assume everyone has sensory-based thoughts; those with imagery in some sensory-modality (say visual and gustatory) and not any other (auditory, tactile, etc.,) often assume everyone relies on the sensory-types they experience and don't experience any others; while most *non-imagers* assume that all this talk about sensations 'inside the mind' are merely metaphorical (Faw 2009; Reisberg, Pearson, and Kosslyn 2003). For example, take two friends, Farah, and Charlie, who are recalling the eye-colour of a mutual friend, Renee. Farah 'just knows' that Renee has brown eyes and Charlie relied upon inspecting a visual-image of Renee's face to 'check for' brown eyes, yet both friends assume that the other recalled the eye-colour in the same way.

Assumptions that everyone thinks the same (as we do) have contributed to fierce debates over how (all) humans think: with mental imagery being both lauded as necessary for ordinary thinking processes and dismissed as a potentially detrimental curiosity (Faw

[82] Exceptions to this are proposals that attempt to reduce the diversity of thinkin experinces into a set number of mutually exclusive 'thinking styles', such as the verbaliser-visualiser dichotomy view of cognitive styles (e.g., Richardson 1977).

2009; MacKisack et al. 2016, 13–14). Along the way, a tumultuous history of these debate has led to various entrenched associations that obscure individual variability. I will explore how these associations emerged in Chapter Four.

Briefly, some definitions of mental imagery specify that these are *internal* experiences that resemble perception despite occurring in the absence of relevant external sensory stimulation (Stephen M. Kosslyn, Ganis, and Thompson 2010, 3; Roeckelein 2004, 11, 68; Waller et al. 2012, 293; Tian and Poeppel 2012). Indeed, as discussed in more detail later, reports of mental images experienced within perceptual space are rarely taken into consideration and, even if they are, these 'externally' located SLMP are considered undesirable. Similarly, despite significant evidence to the contrary, approaches to investigating mental imagery frequently emphasise that subjects have volitional control over their mental imagery (e.g., Roeckelein 2004, 11, 68; Waller et al. 2012, 293).

This typical characterisation of mental imagery as voluntary has dominated the research into ordinary SLMP. Indeed, as Joel Pearson and Fred Westbrook (2015, 278) note, what is typically referred to as 'mental imagery' are the products of voluntary recall. However, mental images can be considered an aspect of ordinary memory even when not generated voluntarily. An evocative example of ordinary spontaneous cognitions involving imagery is the 'earworm' – "the experience of a piece of music that comes unbidden into the mind and repeats outside of conscious control" (Williamson et al. 2012, 261). Likewise, people often experience vivid and spontaneous visual images when they "recall something they did not expect to recall" (D'Angiulli et al. 2013, 1). These examples demonstrate that, as Joel Pearson and colleagues (2015, 590) argue, "not all mental imagery need be voluntary; external events or internal associations can also trigger a mental image, even if one does not want to experience the image at that time".

The existence of spontaneous imagery is not news. For example, French (1902, 47) reported that 11% of the respondents of his mental imagery questionnaire responded 'no' to the question: "Have you a good command of your images?". However, interest in spontaneous imagery has been sporadic and remains isolated from mainstream experimental practices (Hackmann and Holmes 2004). Indeed, even when unbidden mental images are acknowledged, the focus remains on those that are amendable to volitional control (Brewin et al. 2010, 211; Richardson 1969, 43). As such, research into involuntary visual imagery has been overshadowed by both the dominant uses of the concept of mental imagery (Brewin et al. 2010, 210) and the clinical focus on verbal thoughts (Hackmann and Holmes, 2004). As such, interest in uncontrolled imagery is usually only of interest in relation to psychopathology (Joel Pearson and Westbrook 2015, 278).

In addition to the dominance of research into internal voluntary mental imagery, there has been remarkably little research into the different modalities of imagery experiences. Instead, the majority of research focuses on the role of visual imagery (Hubbard 2010, 302). When investigated at all, auditory imagery is often subsumed within broader topics or given a cursory mention. Even as other modalities re-emerge as topics of investigation, approaches typically rely on extensions of the research on visual imagery (Lacey and Lawson 2013b, 2). As such, regardless of the modality investigated, ordinary experiences of mental imagery are all characterised in the same way: they are internally located, voluntary, amenable to control, and easily recognisable as a self-generated mental experience that resembles perceptual stimuli. Indeed, when used within neuroimaging experiments the concept of mental imagery relies on these characteristics to individuate ordinary experiences of SLMP for investigating the role of SLMP in various neurocognitive functions.

3.2 Hallucinations

Turning to the concept of hallucinations, definitions pivot on descriptions of a compelling sense of perception that occurs despite the absence of relevant sensory stimulation.[83] Although considered less amenable to introspection, some examples should illustrate how hallucinations conceptualise SLMP that are experienced with a 'compelling sense of perception'. One famous example is a report by the pseudonymous Jonathan Lang (1938, 1093) of an hallucinatory experience while out walking:

> "The door of a house about 15 yards in front of me opened, and a young lady stepped out and started walking down the sidewalk in front of me. I recognized her… but otherwise did not know her. Every aspect of her appearance was exactly lifelike; her figure was perfectly three dimensional; it was opaque. And every time that her heels struck the sidewalk I distinctly heard the click of their contact with the sidewalk. After the figure had kept ahead of me for about two blocks, I happened to look down; when I glanced up again, the figure had vanished. It had been passing a vacant lot, and there was no house for it to have gone into it".

Another first-hand description is provided by Alvin Goldstein's (1976, 424–25) report of laying alone in hospital and hearing his "children's individual voice qualities and intonations" despite knowing his children were far away. For Goldstein (1976, 424–25), this experience was hallucinatory because he was convinced that the voices come "unmistakably… from the air vents on the door". In a more recent first-person account of auditory hallucinations, Steven Scholtus (2012) describes being able to 'hear' unknown male and female voices as loud, clear, and distinct from his own thoughts. Complementing this in

[83] In this thesis, hallucinations (and related terms) indicate those conscious endogenous experiences that occur in the waking state (in any sensory modality) and fall under this core definitions. For an outline of broader applications of hallucinations see (Blom 2010). For examples of this core definition in use, see (Blom 2010; Farkas 2013; Jardri and Sommer 2013; Peyroux and Franck 2013; Shine et al. 2011; Stephane 2013; Tuleya 2007).

the visual modality, a case report by Ramon Mocellin *et al.,* (2006, 744) describes a young patient who "saw 'hundreds of little spikes' coming in and out of the floor and small ants moving on regularly patterned surfaces".

As these examples suggest, it is the compelling sense of perception that is considered the defining essence of hallucinations (André Aleman and Larøi 2008, 15). Attempts to explain this essence have generated a range of additional stipulations as to what characterises true hallucinations. In the process, a number of more restrictive definitions have included or excluded specific SLMP "depending on the presence or absence of a given characteristics" (Stephane 2013, 86–87). Of these, the commonly emphasised characteristics for hallucinations specify that the SLMP are vivid, involuntary, uncontrolled, externally located, misattributed to an external source, and confused with perception (André Aleman and Larøi 2008, 16, 171; Barnes et al. 2003; David 2004, 109; Larøi et al. 2012, 724; Mast 2005, 739).

These additional definitional criteria for classifying hallucinations are sometimes implied by contrasting the SLMP experience of interest with other types of SLMP. This type of approach is especially prominent in the older continuum models that positioned hallucinations as the extreme end of a spectrum of ordinary imagery (e.g., Saba and Keshavan 1997, 185–86). These older continuum models therefore position hallucinations as dysfunctional mental imagery. However, as detailed later, these imagery-continuum explanations for hallucinations have largely fallen out of fashion (David 2004; Badcock and Hugdahl 2012b).

More common are proposal that hallucinations are due to dysfunction within a range of alternative neurocognitive processes: including language, perception, and metacognition (e.g., Andrè Aleman and Vercammen 2013; Dollfus, Alary, and Razafimandimby 2013; Rossell 2013; Varese and Larøi 2013; Woodward and Menon 2013). Most of these explanatory attempts focus on the specific experience of 'hearing' voices – typically conceptualised as auditory-verbal hallucinations (AVH). However, hallucinations can occur in each modality and, occasionally, as mixed-modality experiences (Stephane 2013, 87).

Indeed, despite the single-modality focus, the goal is usually to identify the disrupted neurocognition responsible for all hallucinations (Larøi et al. 2012; Larøi and Woodward 2007; Santhouse, Howard, and Ffytche 2000, 2062). For example, while the metacognitive failure model was developed to explain AVH, this model has been extended to explain hallucinations in other modalities (Varese and Larøi 2013, 155). Similarly, the mechanism for visual hallucinations described by Shine et al., (2014, 63) was proposed to have "the potential to act as a 'common ground' between studies of hallucinatory phenomena in different neuropsychiatric disorders".

This expectation of a modality-independent mechanism for all hallucinations regardless of disease dominated the nineteenth- and twentieth-centuries (Berrios and Marková 2015, 4). As discussed in the following chapter, this expectation has always sat at odds with the difficulty of bounding the concept of hallucinations.[84] In addition, the twenty-first century has seen criticisms of this expectation return with vigour. These include renewed interest in the different characteristics of hallucinations associated with different diseases (Stephane et al. 2003, 186); in the modality-specific mechanisms for the pathology of hallucinations (Fernyhough and McCarthy-Jones 2013, 101; S. S. Shergill, Cameron, et al. 2001); and in the possibility that, even within a given modality, there are "several categories of hallucination, each with a different neurobiological cause" (Ffytche 2013, 60).

One response to this variability in hallucinatory experiences has been to propose a reformulated continuum hypothesis for hallucinations. In contrast to the older continuums, this reformulation ignores mental imagery to instead broaden the concept of hallucinations

[84] For some overviews, see (Berrios and Marková 2012; Telles-Correia, Moreira, and Gonçalves 2015).

to include those SLMP with a compelling sense of perception reported by otherwise healthy individuals. For example, according to the American Psychological Association, hallucinations are usually an indication of abnormality; yet may occasionally be experienced by 'normal persons' (Tuleya 2007, 129). In line with this extension, the heterogeneity of same-modality hallucinations has led to clinical interest in the negative emotional-valence of hallucinatory experiences. Although offering new insights, this focus on *emotional-valence* typically sits alongside the reliance on typical characteristics (e.g., de Leede-Smith and Barkus 2013, 5–6; Larøi et al. 2012, 725).

Other clinically-focused approaches have proposed that intersectional biopsychosocial processes are involved in experiencing hallucinations as distressing. For example, the distress associated with hearing-voices has been proposed to stem from traumatic experiences (Berg et al. 2015; Daalman et al. 2012; Jones and Coffey 2012; Longden, Madill, and Waterman 2012; F. Waters, Woods, and Fernyhough 2014). Additionally, Frank Larøi suggests that hallucination characteristics – such as frequency, appraisal, and content – are impacted by the culturally specific ways that unusual experiences are conceptualised and treated (F. Waters, Woods, and Fernyhough 2014, 26). Similarly emphasising psychosocial processes, the distress associated with hearing-voices has been proposed to be a function of what people believe about those voices (Andrew, Gray, and Snowden 2008; Strauss 2014).

These types of studies have contributed to clinical interest in understanding the range of factors contributing to distress, rather than in eliminating hallucinatory experiences entirely. Reflecting these recent shifts, "the social determinants of hallucination onset and recovery" was listed as the top research 'hot spot' identified at the second *International Consortium on Hallucination Research* (F. Waters, Woods, and Fernyhough 2014, 27). Even so, hallucinations remain an important diagnostic category. For example, within the 'decision tree' for diagnosing hallucinations in the DSM-5 they are defined as a symptom of psychotic disorders (American Psychiatric Association 2013b). All other mentions of hallucinations within the DSM-5 are positioned in relation to this definition: with psychotic hallucinations used as additional specifying diagnostic criteria (such as in bipolar-related disorders and depressive disorders); or as exclusionary criteria (such as in sleep-wake disorders and trauma-related disorders) (American Psychiatric Association 2013a).

These DSM diagnostic criteria are commonly used in research practices that investigate the pathophysiology of experiences that fall within the 'domain of mental illness' (Poland 2014). In this context, the same substantive, and methodological assumptions inherent in the DSM framework also contribute to research practices. According to Jeffrey Poland (2014, 45), these assumptions include the view of mental disorder as distinct from normal functioning, and the expectation that these disorders have an identifiable pathophysiology. Given these assumptions, the use of DSM categories in research practices have been criticised (e.g., Pierre 2010; Poland 2014; Tabb 2015). These types of criticisms have led to proposals for alternative approaches to classifying objects of psychiatric research. For example, the Research Domain Criteria (RDoC) framework seeks to integrate knowledge of hallucinations from multiple areas of research: from genetic studies to studies based on subjective descriptions of hallucinatory experiences (F. Waters, Woods, and Fernyhough 2014, 26).[85] However, despite proposals such as this, the concept of hallucinations is still typically used as a stable tool for individuating experiences of SLMP diagnosed as symptomatic of psychopathology.

3.3 Distinguishing Characteristics of Mental Imagery and Hallucinations

The concepts of mental imagery and hallucinations are used for investigating the neurophysiological processes underlying ordinary or pathological SLMP respectively. As

[85] The use of the RDoC framework also has a number of problems, see: (Tabb 2016).

detailed earlier, this function relies on each of these concepts individuating between experiences of SLMP that *resemble* perception (mental imagery) on the one hand, and SLMP with a *compelling sense* of perception (hallucinations) on the other. As summarised in Table 1, those SLMP characteristics used to explain this distinction can be collected into broad types: 1) degree of perceptual similarity; 2) reported location; 3) attribution of source; 4) degree of volitional control; and 5) degree of insight. To review from earlier, mental images are characterised as SLMP that are easily distinguishable from external stimuli due to a low degree of perceptual similarity and/or their experience as internally self-produced copies of sensation that are voluntary and/or controllable (Stephen M. Kosslyn, Ganis, and Thompson 2010, 3; Roeckelein 2004, 11, 68; Waller et al. 2012, 293). In contrast, confusing SLMP for perceptual reality is associated with the compelling sense of perception of hallucinations and is typically attributed to (and measured by) various characteristics of the SLMP experience.[86] For example, Massoud Stephane and colleagues (2003, 187) identified twenty variables of the reported characteristics of AVH. Of these, a smaller selection of characteristics are typically considered most relevant to the pathological process of hallucinations: the abnormally high degrees of perceptual similarity; abnormal frequency and duration; reported location within external perceptual space; belief that the SLMP originates from a nonself source; and/or a lack of volitional control (A. Aleman 2001; Slade and Bentall 1988; David 2004; Ratcliff, Farhall, and Shawyer 2011).

When contrasted, the typical characteristics of each concept appear as the inverse of those typical of the other.[87] As discussed later, these inverse characterisations are implicitly

[86] Note that psychological factors – such as interpretations of, and attitudes towards, hallucinatory content – are increasingly considered as well (Ratcliff, Farhall, and Shawyer 2011, 530). I will discuss these briefly later (primarily as they relate to the more commonly attributed characteristics).

[87] This point extends on Lisa Blackman's (2001, 51) argument that there is a contrasting co-dependent relationship between the characteristics of auditory-imagery and auditory hallucinations.

embedded in the independent uses of the concepts of mental imagery and hallucinations for investigating ordinary and pathological SLMP respectively. However, it is important to first examine whether the characterisations of the concepts of mental imagery and hallucinations operate to reliably differentiate between ordinary and pathological forms of SLMP in the first place. To this end, I will briefly consider each type of distinguishing characteristic in turn.

Table 1: Typical characteristics associated with either mental imagery or hallucinations

	Mental Imagery	Hallucinations
Perceptual Similarity	Variable vividness of SLMP Fleeting SLMP Tentative SLMP	Abnormally vivid SLMP Concrete SLMP Palpable SLMP
Reported location	Internally located SLMP not within perceptual space	Externally located SLMP within perceptual space
Volition and Control	Effortfully generate SLMP Manipulable SLMP Dismissible SLMP	Spontaneous SLMP Obstinate SLMP Absorbing SLMP
Attribution of Source	Self-attributed	Not self-attributed
Level of Insight	Insight maintained: recognition that SLMP are not perceptions	Lack of insight: belief that the SLMP are perceptions

3.3.1 Perceptual Similarity

The degree of perceptual-similarity of SLMP is often measured in terms of the relative *vividness* of the SLMP experience in comparison to actual perception. This degree of vividness played an especially prominent role in theories that explained the *compelling sense* of perception experienced as hallucinations as due to an experience of mental imagery with an abnormal degree of perceptual-similarity (e.g., E. Brett and Starker 1977; Saba and Keshavan 1997, 185–86).

Within this context, two opposing theories attempted to explain why ordinary imagery might attain such a high-degree of perceptual similarity that they became hallucinations (D. J. Smith 1992, 154). One approach was to position hallucinations as due to abnormally vivid imagery appearing too much like perception. For example, in the words of Robert Roman and Carney Landis (1945, 327), "hallucinatory experiences… are exaggerations of normal processes which somehow get out of control [and] might be thought of as mental images which become more vivid and compelling than ordinary imagery". An alternative suggestion was that, if individuals with minimal experience of imagery are insufficiently preparing to control rarer SLMP, hallucinations might result from an abnormally poor abilities to voluntary generate imagery (e.g., E. Brett and Starker 1977, 395).[88] These types of theories led to investigations into whether a susceptibility to hallucinate correlated with the degree of mental imagery vividness (A. Aleman, Böcker, and de Haan 2001; Mintz and Alpert 1972; Oertel et al. 2009; E. Brett and Starker 1977).

Even so, it is rare to rely upon the differing degrees of perceptual-similarity as an isolated characteristic for distinguishing between mental imagery and hallucinations. Instead, this characteristic is combined with another to explain why mental imagery merely resembles

[88] A recent twist changes the causal direction: with imagery dysfunction in schizophrenic patients suggested to "reflect deficiency in the voluntary control of imagery, or over-taxing of imagery processes caused by persistent hallucinatory or delusional states" (D. G. Pearson et al. 2013, 8–9).

perception while hallucinations have a compelling sense of perception. For example, when describing musical hallucinations as able to be as loud as hearing and with an externally-sourced perceptual quality, Oliver Sacks and Jan Dirk Blom (2012, 134) note that "imagery never rivals perception in this way".

There are several reasons for this reliance on additional characteristics. The reason I will focus on is that experiences of SLMP conceptualised as mental imagery and hallucinations cannot be differentiated based on comparing their degree of perceptual similarity alone. Firstly, there has been a long history of reports documenting a range of variability in the perceptual-similarity of ordinary mental imagery. This variability includes ordinary images felt to be "as vivid as the actual experience" (Betts 1909, 5; D. G. Pearson et al. 2013, 273). As an example of imagery being as vivid as perception, French (1902, 52–53) reported one subject could be "tasting in memory one food while eating another…but that while doing so [she] could not taste the food [she] was in reality eating". More recently, Hoffman et al., (2008, 1168) noted that "one can wilfully imagine verbal imagery 'cast' in a louder voice or in a non-self speaking voice". Indeed, as long as images are voluntary and investigated in isolation from hallucinations, higher degrees of imagery vividness typically indicate greater imagery 'ability' (Lacey and Lawson 2013a, 273; Reisberg, Pearson, and Kosslyn 2003, 157). For example, surveys frequently measure imagery on a scale from 'poor' to 'excellent' vividness: with mean results "closer to the vivid end of the continuum" (Faw 2009, 12). Indeed, a proposed symptom of depression is that the patient "may find it hard to generate vivid future- or past-oriented positive mental images" (E. A. Holmes et al. 2016, 255).

There are also reports that, as with imagery, hallucinations are experienced with an extensive range of vividness. For example, experiences of AVHs range from shouting to soft whispers and indistinct mumbles (Larøi et al. 2012, 725; D. J. Smith 1992, 158–59). Indeed, these reports have led to the suggestion that the intensity of hallucinations "may vary from barely perceptible to overwhelmingly intense" (Landis and Mettler 1964, 113). Given this, the view that hallucinations have a higher degree of vividness than mental images has been explicitly challenged (G. R. Gray 2010, 244; Kunzendorf and Sheikh 1990, 186). In one such challenge, Mintz and Alpert (1972, 310) proposed that the pathology of hallucinations requires not only a high degree of imagery but also an impairment of 'reality testing' abilities. More recently, Hoffman et al., (2008, 1171) reported that the loudness and clarity of the voices was rarely an important factor for schizophrenic patients when differentiating AVH from ordinary verbal thought. In line with arguments such as these, proposals that vivid imagery increases susceptibility to hallucinations have been largely abandoned (Hubbard 2010, 317). Indeed, a recent review of research into hallucinations reported that imagery vividness and the tendency to hallucinate are functionally independent (Badcock and Hugdahl 2012a, 433).

Contemporary metacognitive models of hallucinations rarely consider perceptual-similarity important; focusing instead on the failure to monitor and control the intrusion of (verbal or imagery based) thoughts (Varese and Larøi 2013, 155). Indeed, perceptual similarity is no longer regarded as a plausible candidate for explaining the compelling reality of hallucinations (Farkas 2013, 413). As such, this characteristic offers little to help explain how the concepts of mental imagery and hallucinations individuate discrete types of SLMP for investigating ordinary and pathological neurocognitive processes respectively.

3.3.2 Reported Location

As evident in the earlier quote from Sacks and Blom, the relative location of SLMP experiences are often included along with the degree of vividness to help distinguish between mental imagery and hallucinations. In addition, reported location is sometimes presented as the key distinguishing characteristic. This distinction is exemplified in the argument that the image and what the image is of do not exist in the same logical space no matter how vivid –

while a "hallucinated dagger may appear to Macbeth to be three feet in front of him… a mental image cannot *appear* or *seem* to be located anywhere" (Bennett and Hacker 2003, 191). This type of characteristic differentiates between those SLMP reported within the 'mind' or 'head' (internal) and those reported as located within perceptual space (external). However, the contrasting characterisation of mental imagery as 'internal' experiences of SLMP and hallucinations as 'external' experience of SLMP also fails to reliably differentiate between ordinary and pathological SLMP.

Firstly, while still typically characterised as 'internal', reports of mental imagery have also challenged the necessity of this criteria. For example, first-person reports of mental imagery have located these SLMP within external perceptual space (Craver-Lemley and Reeves 1992, 192). Secondly, reports of hallucinations indicate that these SLMP are frequently experienced as 'internal'. For example, in a first-person report of a visual hallucinatory experience, the visions were described as located 'in his mind' (Mott *et al.,* 1965: 599). Similarly, the AVH of individuals diagnosed with schizophrenia commonly include internally located experiences (Judkins and Slade 1981; John Junginger 1986; J. Junginger and Frame 1985; McKague et al. 2012; Scholtus and Blanke 2012). Indeed, Hoffman et al., (2008, 1170–71) reported that only 26.6% of their subjects described their 'voices' as emanated exclusively from outside their head. Secondly, even when hallucinations are experienced as originating externally they may not be integrated into external perception (Mast 2005, 752). In line with this, the perceived location of hallucinations does not necessarily correlate with the patient's view of the experience as negative or distressing (D. L. Copolov, Mackinnon, and Trauer 2004, 168).

Given this, the characterisation of hallucinations as projected into external space has been discarded in some contexts (e.g., David 2004, 110–11; D. Copolov, Trauer, and Mackinnon 2004, 4). As such, reported location also fails to explain why the concepts of mental imagery and hallucinations can be used independently of each other to investigate ordinary and dysfunctional experiences of SLMP respectively.

3.3.3 Source Attribution

Regardless of whether SLMP are located internally or externally, the ability to correctly attribute the source of SLMP to oneself (imagery) is frequently contrasted with the misattribution of the source of SLMP to a nonself source (hallucinations) (e.g., S. S. Shergill, Bullmore, et al. 2001). In addition, the characteristic of source attribution provides a defining feature of the concepts of mental imagery (self-attribution) and hallucinations (attributed to another) even when the two concepts are used independently of each other. Firstly, while the idea that mental images are self-attributed is rarely explicitly stated, it is often implied through a combination of other characteristics. For example, as discussed in the next section, the idea that an internal and voluntary SLMP could be attributed to anything other than ourselves can present an uncomfortable challenge to our sense of self-control.

Secondly, a lack of self-attribution is central to multiple contemporary theories of AVH pathology. For example, some models of AVH propose that the sense of self-generation that accompanies ordinary passive thoughts 'goes awry' in hallucinations (Ford and Hoffman 2013, 361). These models often emphasise metacognitive dysfunction: the failure to adequately monitor and control ordinary internally generated events (of which mental imagery is just one). For example, Filippo Varese and Frank Larøi (2013, 154) note that, while the underlying processes of hallucinations remain contested, the emerging consensus is that hallucinations originate from internally generated cognitive events – whether images or verbal thoughts – being misattributed to an external source.

However, while offering more traction than perceptual similarity or reported location, source-attribution also runs into challenges when attempting to differentiate between mental imagery and hallucinations for investigating ordinary and pathological SLMP. One challenge is that, as Verese and Larøi (2013, 161) note, "metacognitive beliefs might be associated with psychological distress in general" and, as such, may not causally relate to the phenomena conceptualised as hallucinations so much as the distress these SLMP may cause. Another challenge has emerged from the reported heterogeneity of hallucinatory experiences. For example, some psychiatric patients attribute their hallucinations to an internal-source such as brain damage (Larøi et al. 2012, 728). Likewise, a study of AVH experiences in patients diagnosed with borderline personality disorder found that the "majority believed their voices to originate from an internal cause" despite not having complete control of the experience (Larøi et al. 2012, 728). In addition, Lacey and Lawson (2013, 423) note that Parkinson's patients identify their involuntary SLMP as hallucinations even though they do not misattribute them to perceptual sources.[89] Meanwhile, a significant proportion of the non-clinical population report hallucinatory-like experiences that are attributed to an external source (Hill and Linden 2013; Johns 2005; Johns et al. 2014; Larøi et al. 2012; Vellante et al. 2012). Indeed, de Leede-Smith and Barkus (2013, 5) reported that, along with loudness and localisation, the 'explanation of origin' characteristics was indistinguishable between clinical and non-clinical experiences of AVH.

This heterogeneity in the source-attribution of hallucinations calls into question the reliability of this characteristic in distinguishing the concept of hallucinations from that of mental imagery. Furthermore, these examples highlight that identifying SLMP that are misattributed to a nonself source does not necessarily help to individuate a uniquely dysfunctional type of SLMP. As such, source-attribution characteristics also fail to adequately

[89] Indeed, it has even been proposed that, "the diversity within the phenomenology of AVH could reflect equally diverse neural mechanisms" that would add to any final pathway identified as common for all hallucination types (Stephane et al. 2003, 187, 192).

explain the independent uses of the concepts of mental imagery and hallucinations for investigating ordinary and dysfunctional experiences of SLMP respectively.

3.3.4 Volitional Control

An alternative characteristic distinction between mental imagery and hallucinations emphasises their differing levels of reported volition and/or control (Hill and Linden 2013, 38; Larøi et al. 2012; Mast 2005). For example, Philip R. Saba and Matcheri S. Keshavan (1997, 190) proposed that a "lack of volitional control over the [SLMP of] music may be used to separate musical hallucinations from the non-pathological phenomenon of musical imagery". This distinction is also evident when the concepts are each used independently. For example, mental images are predominantly characterised as entirely voluntarily or, at the very least, under volitional control (Andrè Aleman and Vercammen 2013, 114; Roeckelein 2004, 11, 68; Waller et al. 2012, 293). In contrast, hallucinatory experiences are characterised as both involuntary and uncontrolled (Badcock and Hugdahl 2012a, 433; David 2004, 110).

However, the value of distinguishing between mental imagery and hallucinations based on degree of volitional control is challenged by two intersecting points: ordinary mental imagery is not always under volitional control (Joel Pearson et al. 2015, 598); and a lack of volitional control is not required for hallucinations to be experienced as distressing (R. E. Hoffman et al. 2008). For example, Hoffman et al., (2008, 1168) reported that subjects did not rely on uncontrollability for identifying AVH, and note that "some patients may be able to exert at least partial control of their voices". As such, the value of volitional control (or the lack thereof) as a distinguishing characteristic has been abandoned in some contexts. In these contexts, other typical characteristics are relied upon instead. For instance, involuntary musical imagery are distinguished from musical hallucinations because the latter are distressing, have a greater degree of perceptual similarity, and tend to be attributed to an external source (Brown 2006, 29; Sacks and Blom 2012, 134). Likewise, involuntary visual images are distinguished from hallucinations by their reported location and associated levels of insight: imagery are merely internal representations of perceptions while hallucinations are "mental experiences believed to be external percepts" (Joel Pearson et al. 2015, 598).

Meanwhile, taking the ability of subjects to ameliorate their hallucinatory experiences into consideration, David (2004, 110) suggests that, even when subjects do have some degree of control, hallucinations can be distinguished from mental imagery because patients do not *feel* in control of hallucinations. In explaining a similar distinction, Hoffman et al., (2008, 1172) raised the possibility that the aberrant *content* of AVH might "prompt patients to infer that these experiences are not under their control". This argument suggests that it is not that the experience of SLMP is uncontrolled that is distressing; rather, it is the feeling that it is uncontrollable due to other factors (such as content). As such, when a lack of volitional control has been shown to be of little value in distinguishing distressing SLMP from positive or neutral experiences of SLMP, other types of criteria have been relied upon when the need to differentiate hallucinations from mental imagery is considered.

Volitional control is therefore unable to provide a clear distinction between the concepts of mental imagery and hallucinations as used for ordinary and pathological experiences of SLMP. However, it is possible that volitional control provides a valuable characteristic for distinguishing between desirable and undesirable experiences of SLMP more generally. Indeed, Pearson and Westbrook (2015, 278) draw attention to a voluntary-involuntary gap in the research on phantom perceptions. In line with this approach, unbidden vivid SLMP have been conceptualised as 'intrusive' mental images: a distressing symptom in a range of psychiatric conditions (E. A. Brett and Ostroff 1985; Brewin et al. 2010; Di Simplicio et al. 2012; Ng, Krans, and Holmes 2013; Speckens et al. 2007).

Nonetheless, there are still some challenges to relying on volitional control for distinguishing between ordinary mental imagery and pathological hallucinations. Firstly, it is not yet clear how this research on intrusive imagery converges with the research on the role of ordinary involuntary imagery mentioned earlier. Furthermore, even when involuntary mental images are experienced as *distressing* (potentially due to a lack of volitional control) they are still distinguished from hallucinations. For example, 'intrusive mental imagery' and hallucinations are both experiences of SLMP that are involuntary and distressing yet are considered distinct because insight is retained in mental imagery but not in hallucinations (e.g., M. Martin and Williams 1990, 268).

These considerations suggest an intersection of multiple distinctions that each draws on the characteristic of volitional control:

i. Firstly, a distinction between ordinary mental imagery and hallucinations on the one hand and between voluntary mental imagery and, on the other, those uncontrollable vivid imagery considered symptomatic of various of psychopathologies (e.g., Joel Pearson and Westbrook 2015, 278);
ii. Secondly, a distinction between ordinary mental imagery on the one hand and both pathological and non-pathological hallucinations on the other (e.g., Linden et al. 2011; Mast 2005, 739);
iii. And, thirdly, a distinction between pathological hallucinations on the one hand, and both non-pathological hallucinations and mental imagery on the other (e.g., Badcock and Hugdahl 2012a, 434).

Comparing each of these distinctions accentuates how involuntary and uncontrolled SLMP have been conceptualised as both hallucinations and as mental imagery in different contexts; an overlap that occurs regardless of whether the SLMP in question are experienced as pathological or non-pathological. Furthermore, while lack of control continues to feature in theories of distressing SLMP (whether conceptualised as mental imagery or hallucinations) this is closely linked to whether the content experienced is positive or negative (Beaman and

Williams 2010, 643; Larøi and Woodward 2007, 725). Therefore, rather than an intersection, there appears to be an overpass where multiple concepts for SLMP are each distinguished from multiple other concepts based on the inconsistent criteria of the presence/absence of volitional control – a distinction that can only be maintained if each conceptual distinction operates separately from all the others.

Although valuable for the cross-pollination of research into various conceptualisations of SLMP, a voluntary-involuntary distinction fails to provide a reliable indication for when SLMP are either ordinary (or at least desirable) or undesirable (as potential symptoms of pathology). Therefore, distinguishing between the concepts of mental imagery and hallucinations as mutually exclusive experiences of SLMP that are either ordinary or pathological is also insufficient for justifying why the role of SLMP in functional and dysfunctional neurocognitive processes are investigated independently of each other.

3.3.5 Level of Insight

The 'level of insight' characteristic is one of the most promising distinctions between those experiences of SLMP that are recognised as such (mental imagery) and those compelling sensations confused for actual perception (hallucinations). In this context, a 'lack' of insight occurs when an individual *believes* that SLMP are perceptual experiences. This "illusion of reality" has been described by Richard Bentall (1990, 82) as a characteristic of all hallucinatory experiences. It also readily complements the claim that "we rarely confuse mental images with percepts" (Mast 2005, 769). Indeed, that an individual can tell that that their mental imagery is distinct from perceptual reality is often taken for granted; especially when other typical characteristics of volitional control and internal location of the SLMP are emphasised.

Lack of insight has often been explained to be a result of the external location, nonself attribution, and/or higher degree of perceptual similarity of hallucinations. However, as just discussed, external location, nonself source-attribution, and high degree of perceptual similarity offer insufficient explanations for the compelling sense of hallucinations as perception. For example, even when pathology is determined by belief in the nonself origin of SLMP, phenomenological studies of voice-hearing suggest that this belief varies independently from the degree of perceptual similarity of the sensory experience (Stephens and Graham 1994, 182–86). In a related argument, Katalin Farkas (2013, 411) regards the involuntary experience of hallucinations as the only necessary characteristic for a sense of reality. However, while the involuntary experience of SLMP may be necessary for a compelling sense of perception it cannot be sufficient – as evident from the preceding discussion.

An additional approach is to rely on the levels of insight (about whether an experience of SLMP is indeed a sensory-like experience rather than perception) to justify the distinction between mental imagery (as readily distinguishable from perception) and hallucinations (as confused with perception) for the purposes of investigating ordinary or pathological SLMP. However, this justification relies on two assumptions: that ordinary SLMP are readily distinguishable from perception and that SLMP are pathological due to being confused for perception. Once again, these assumptions have been repeatedly challenged. In the first case, there is evidence that ordinary mental images can both interact with perceptual processes and be confused with perceptions. For example, Perky (1910) investigated the difficulty of distinguishing between perceived stimuli and ordinary images of the same object. Indeed, there might even be bidirectional influences between imagery and perception that influence the generation and modification of (potentially false) memories (Joel Pearson, Rademaker, and Tong 2011).

In the second case, pathological hallucinations are often recognised as distinct from perception. Indeed, the criteria that there is always a 'lack of insight' during the experience of hallucinations has been explicitly questioned (G. R. Gray 2010, 244). For instance, even when initially misattributed to a nonself source, hallucinations persist after an individual is aware that their SLMP are distinct from perception. For example Steven Scholtus (2012, 106) describes how he initially attributed his 'voices' to paranormal sources, but then accepted these hallucinations as self-produced (after learning that they were governed by neurobiological processes). In addition, there have been numerous reports of hallucinatory experiences being recognised as distinct from the compellingly real perception they resemble. For example, when introducing a collection of subjective accounts of hallucinations, Landis and Mettler (1964, 114) note that, in contrast to delusions, hallucinations "may or may not be considered unreal by the person having the experience". Likewise, in the earlier account of AVH by Alvin Goldstein (1976, 424–25), his "perceptions where compelling" yet he became aware at the time that what he was perceiving was highly unlikely, even absurd. Furthermore, these compelling real sensations continued even after his insightful realisation that he was in the middle of an hallucinatory experience (Goldstein 1976, 425).

While there are other examples, these two misplaced assumptions converge to suggest that mental images are not as readily distinguished from perception as often thought; that hallucinations are not always confused for perceptual reality; and that, even when SLMP are confused for actual perception, it is not necessarily a sign of dysfunction. As such, the 'level of insight' type of characteristic also fails to provide a reliable explanation for how the concepts of mental imagery and hallucinations reliably distinguish distinct types of ordinary and undesirable SLMP for investigating functional and pathological experiences respectively.

3.3.6 Emotional-valence

From the preceding sections it should be clear that the typical characteristics for differentiating between mental imagery and hallucinations fail to reliably individuate discrete types of SLMP that can be conceptualised as either archetypically ordinary or necessarily undesirable (let along pathological). However, this does not mean that there is no way to reliably distinguish between experiences of SLMP that are positive (useful) or negative (distressing). The potential of this approach was gestured to in my earlier attempts to navigate the complex overpass of (independent yet overlapping) concepts for both ordinary and pathological SLMP. As such, it is worth clarifying these various conceptualisations of SLMP as each relate to the typical characterisations of ordinary mental imagery and pathological hallucinations.

For example, as summarised in Table 2, the characterisation of typical (i.e., ordinary) mental imagery provides the base-line for attempts to characterise variations such as *spontaneous mental imager*y and *intrusive mental imagery.* This seems unremarkable until compared with a comparison, summarised in Table 3, of how the characterisations of typical hallucinations differs from those associated with adaptations of this concept such as *clinically-relevant hallucinations* and *non-pathological hallucinations*. Maintaining the same shading scheme as in Table 1, highlights the overlaps between Table 2 and Table 3. [90] For example, most characteristics that are typically associated with hallucinations are also associated with these adapted uses of the concept of mental images. Likewise, several of the characteristics typically associated with mental imagery are also associate with the adapted uses of the concept of hallucinations.

[90] Shading key in all tables: green/light-grey indicates typical mental imagery characteristics; purple/dark-grey indicates typical characteristics associated with hallucinations; no-shading indicates something not accounted for in the inverse characterisation of mental imagery and hallucinations.

Table 2: Adapted characterisations of mental imagery

Characteristic	Typical Mental Imagery	Spontaneous Mental Imagery	Intrusive Mental Imagery
Perceptual Similarity	Variable	Variable	High
Location	Internal	Internal	Internal
Volition	Voluntary	Involuntary	Involuntary
Control	Manipulable	Manipulable	Uncontrolled
Duration	Fleeting	Variable	Extended
Attribution	Self	Self	Self
Insight	Maintained	Maintained	Maintained
Subjective Value	Positive	Positive	Negative
Emotional-valence	Benign	Benign	Disruptive
Content	Useful	Variable	Unwanted
Frequency	Variable	Frequent	Frequent

Table 3: Adapted characterisations of hallucinations

Characteristic	Typical Hallucinations	Clinically Relevant Hallucinations	Non-Pathological Hallucinations
Perceptual Similarity	High	not specified	not specified
Location	External	Variable	Variable
Volition	Involuntary	Involuntary	Involuntary
Control	Uncontrolled	Uncontrolled	Uncontrolled
Duration	Persistent	Extended	Fleeting
Attribution	Others	Variable	Variable
Insight	Lacking	Variable	Variable
Subjective Value	Negative	Negative	Variable
Emotional-valence	Disruptive	Disruptive	Benign
Content	not specified	Unwanted	Variable
Frequency	Frequent	Frequent	Variable

In the case of hallucinations, the pathological importance of distress – rather than the notion that experiencing certain types of SLMP are pathological – has contributed to interest in non-pathological hallucinations and changed the characterisation of clinically relevant hallucinations. In relation to non-pathological hallucinations, a range of phenomenological surveys indicate a sizable minority of both the clinical and non-clinical populations that experience hallucinations as neutral, pleasant, or even valued experiences (e.g., D. L. Copolov, Mackinnon, and Trauer 2004, 164, 168; Faccio et al. 2013, 764).[91] In relation to clinically relevant hallucinations, Louise Johns (2005) suggests that "beliefs about hallucinations, negative mood, and perceived lack of control" are more reliable predictors of patient status than the occurrence of hallucinations. Furthermore, as mentioned earlier there has been increasing interest in biopsychosocial factors that might contribute to the distress associated with hallucinatory experiences (F. Waters, Woods, and Fernyhough 2014, 27).

A related proposal is that the positive or negative valence experienced with SLMP depends, in part, on the cultural associations within which the type of SLMP is viewed.[92] This possibility has been highlighted by cross-cultural studies of voice-hearing experiences. For example, Tanya M. Luhrmann and colleagues (2015) compared the voice-hearing experiences of participants living in either San Mateo (USA), Chennai (India), or Accra (Ghana), and found that the relationship between an individual and their hallucinations differed depending on their cultural context:

> "Many participants in the Chennai and Accra samples insisted that their predominant or even only experience of the voices was positive – a report

[91] Although arguments that hallucinations are not, in themselves, pathological are not new, see (e.g., Parish 1902), these more recent arguments have gained more ground then earlier attempts.

[92] Of course, proposing that cultural factors influence whether SLMP are experienced as distressing does not necessarily imply that there are no cross-cultural neurophysiological mechanisms that also contribute. Indeed, Luhrmann *et al.*, (2011, 77) emphasises the likelihood that, while shaped by cultural expectations, distressing hallucinations exist in all cultures and may therefore be a "biological sequelae of psychotic illness".

supported by chart review and clinical observation. Not one American did" (Luhrmann et al. 2015, 42).

This difference in emotional-valence of the SLMP experience was found despite other similarities across the sample: subjects in all groups reported voice content as both 'good' and 'bad' and with variable degrees of perceptual-similarity (Luhrmann et al. 2015, 42). Given the similarity in content and perceptual-similarity characteristics, the difference in emotional-valence was partially attributed to the relationship of individuals to their voices, rather than differences in the SLMP themselves. Notably, participants in the samples from India and Ghana "seemed to have real human relationships with the voices – sometimes even when they did not like them" (Luhrmann et al. 2015, 42). In contrast, this type of positive relationship was far less common in the sample from the USA (Luhrmann et al. 2015, 42).

While these types of approaches include both pathological and non-pathological experiences of SLMP under the concept of hallucinations, there remains a distinction between them. This distinction centres on some typical characteristics of hallucinations (such as lack of volitional control) being present only in addition to the negative emotional-valence of pathological hallucinations. This type of distinction has been taken to suggest that the distress associated with clinical hallucinations has less to do with experiencing a specific type of SLMP and more to do with the appraisal of that experience by the individual and their community (Hill and Linden 2013, 30; Strauss 2014, 50).

In relation to this, a range of approaches have investigated the possibility that distress may be caused by the co-presence of hallucinatory experience and another factor, rather than the SLMP itself (Andrew, Gray, and Snowden 2008; Beavan and Read 2010; Longden, Madill, and Waterman 2012; Sanjuán, Moltó, and Tolosa 2013, 234). Within contexts where this possibility has gained traction, emphasis is therefore being placed on understanding and treating the psychosocial core of the distress experienced rather than eliminating the hallucinatory experience entirely.[93] However, while the possibility of psychosocial factors in the distress associated with hallucinations seems to be gaining support within (bio)psychosocial and service-user led contexts, these factors are rarely accounted for within experimental neuroimaging contexts.[94]

Meanwhile, parallel concerns have emerged in some of the more niche uses of the concept of mental imagery. Firstly, as mentioned earlier stigmatising social attitudes have also been implicated in the lack of interest in auditory imagery (Hubbard 2013b, 240). Elsewhere, in a disconnected context, the concept of mental imagery has also begun to be adapted to investigate the distresses associated with unwanted SLMP (rather than the experiences of SLMP themselves). However, although disconnected, these approaches converge with those discussed above to emphasise that distress might stem from (bio)psychosocial and cultural factors rather than the experience of SLMP *per se*. For example, the existence of intrusive and uncontrolled mental images are not regarded as necessarily pathological in and of themselves (Brewin et al. 2010, 211; Richardson 1969, 43). Rather, Beaman *et al.,* (2010, 643) suggest that intrusive and unwanted imagery "behave like pathological intrusive thoughts [yet] only become so if their content is viewed as sufficiently unpleasant of distressing". Likewise, ordinary mental images have been treated as pathological when they amplify a dysfunctional psychological state (Ng, Krans, and Holmes 2013, 370).

Another parallel with clinical approaches to hallucination is that the distress associated with unwanted mental imagery is also being linked to the psychosocial and cognitive factors associated with trauma (Speckens et al. 2007). As such, comparing the characterisations of non-clinical hallucinations with the characterisation of intrusive mental imagery (in relation

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[93] See: (Andrew, Gray, and Snowden 2008; Daalman et al. 2012; Jones and Coffey 2012; Kalhovde, Elstad, and Talseth 2013; Longden, Madill, and Waterman 2012; Romme et al. 1992; P. Thomas, Bracken, and Leudar 2004).

[94] See *service-user movements* and *hearing-voices* in Appendix 1 (Annotated Glossary).

to the typical characteristics of mental imagery and hallucinations) reveals significant overlap between the characteristics of ordinary and distressing SLMP. For example, both intrusive imagery and non-clinical hallucinations are characterised as internally located and recognised as self-produced (like typical mental imagery) as well as involuntary, uncontrolled experiences of SLMP (like typical hallucinations). Meanwhile, the differences between them appears to be that, while intrusive imagery has unwanted content, negative valence, and a disruptive impact (like typical hallucinations), non-clinical hallucinations can include benign content and be experienced as positive (like typical mental imagery).

This partial overlap between the flexible characterisations of ordinary mental imagery and pathological hallucinations (when they are used in different contexts) reiterates the ambiguous distinctions between them (see Tables 2 and 3). This ongoing ambiguity raises a question: how did each of these concepts become individuated as discrete experiences of ordinary or pathological SLMP in the first place? I will return to this question in the following chapter. For now, it is enough to note that this question is rarely explored. Instead, even as the characteristics traditionally taken to explain the different phenomenological experiences of these two types of SLMP rapidly lose their relevance, each adaptation in the uses of these two concepts maintain their independence from the other. Indeed, these independent uses persist even in the clinical context where psychosocial factors and environmental contexts have been proposed to underlie specific characteristics of pathological SLMP experiences. As such, it is little surprise that these possibilities have yet to penetrate the dominant approaches to neuroimaging investigations into SLMP-neuroanatomical-correlates. For, example, in the case of hallucinations, there continues to be minimal cross-talk between those approaches that focus on environmental and psychosocial causal factors and those that use neuroimaging techniques to investigate abnormal brain function (Sanjuán, Moltó, and Tolosa 2013, 234). Even when neuroimaging approaches take into account broader factors (such as the existence of hallucinatory-like experiences in non-clinical populations, diverse hallucinatory *phenomenology*, and the context-dependence of hallucinatory content) the focus remains on identifying SLMP-neuroanatomical-correlates that indicate the pathological processes disrupting neurocognition (e.g., David 2004, 111–12).[95] Likewise, clinical interest in the role of mental imagery in psychopathology remains largely isolated from the experimental practices within mainstream psychological disciplines (Hackmann and Holmes 2004). As such, experimental uses of the concept of mental imagery assume that these SLMP are valuable aspects of neurocognition.

Therefore, while valuable in a clinical context, a distinction between positive and negative experiences of SLMP still fails to explain how the concepts of mental imagery and hallucinations can reliably individuate specific instances of SLMP for investigating functional and dysfunctional neurocognitive processes respectively. Indeed, the distinction between positive/negative emotional-valence does not even explain why some SLMP have a compelling sense of reality while others do not. Instead, attempting to distinguish between SLMP based on positive or negative emotional-valence typically reduces this distinction to differing degrees of control associated with the concept of either mental imagery or hallucinations. This brings us back to the problem that, as argued above, differing degrees of control are also insufficient for distinguishing between ordinary mental imagery and pathological hallucinations. As such, while promising in a clinical context, delineating between experiences of SLMP based on emotional-valence does not yet provide a clear boundary between the uses of the concepts of mental imagery and hallucinations for investigating functional and dysfunctional experiences of SLMP respectively.

[95] Note that 'normal' in this context can mean a range of things depending on the context (Dumit 2004, 8–9). This point has been specifically highlighted in relation to the role of fMRI scans in legal settings (Tancredi and Brodie 2007, 287).

3.4 Independent Uses of the Concepts of Mental Imagery and Hallucinations

The concepts of mental imagery and hallucinations are often used independently from each other, with minimal acknowledgement of the adapted uses of these concepts within clinical contexts. As outlined earlier, when these two concepts are used in isolation from each other, those characteristics once proposed to explain the differences between these two types of SLMP are now routinely reported for both. On the one hand, mental images are experienced as internal and distinguishable from real perception whether controlled and positive (ordinary) or uncontrollable and negative (intrusive). Meanwhile, hallucinations are experienced as external, indistinguishable from real perception, uncontrolled, and involuntary whether positive (non-pathological) or negative (pathological).

The independent uses of the concepts of mental imagery and hallucinations is most striking in examples where each is used without any reference to the other. For example, in the edited volume on mental imagery of *Frontiers Research Topics* (Joel Pearson and Kosslyn 2013), only one of the sixteen chapters mentions hallucinations.[96] Furthermore, even in this one chapter, the distinction between mental imagery and hallucinations is taken for granted. Indeed, hallucinations are merely included (alongside stuttering and phantom perception) as one of the possible disorders that might stem from a dysfunction in the role of mental imagery in modulating perception (Tian and Poeppel 2012, 157–58).

Likewise, the few mentions of mental imagery within the edited volume *Neuroscience of Hallucinations* (Jardri et al. 2013) all dismiss imagery as either irrelevant to research into the cause of hallucinations or as merely providing the control condition to which hallucinations are compared.[97] Indeed, while still occasionally placed on the same continuum, mental

[96] For similar trends, see (Collet and Guillot 2010; Denis, Mellet, and Kosslyn 2004).

[97] For an example of the former, see (Andrè Aleman and Vercammen 2013, 113–15) For examples of the latter, see: (Dollfus, Alary, and Razafimandimby 2013, 127; Ford and Hoffman 2013, 366).

imagery has become merely one candidate within a range of disrupted normal functions – including language, attentional processes, and memory – that are proposed to underlie hallucinations. For example, in an overview of the cognitive neuropsychiatry of AVH, David (2004, 114–15) reported that the neuroimaging evidence for AVH was "accumulating in favour of mechanisms involving language perception and production", not dysfunctional auditory processing (whether actual or imagined). As detailed earlier, rather than a continuum between mental imagery and hallucinations, the reformulated continuity hypothesis of hallucinations therefore focuses on the difference between different types of hallucination-like phenomena in non-clinical and clinically-relevant experiences (Badcock and Hugdahl 2012b).

Furthermore, even when niche uses of the concepts of mental imagery and hallucinations that present challenges to their typical characterisations are independent of each other. The two less common uses of these concepts I highlighted earlier illustrate this point neatly: clinical interest in dysfunctional mental imagery and surveys of hallucinations reported within the non-clinical population. In the first case, mental imagery is considered abnormal yet is still routinely treated separately from both pathological hallucinations and hallucinatory-like experiences reported in non-clinical populations (e.g., D. G. Pearson and Krans 2017; Larøi et al. 2012, 726; Linden et al. 2011, 330; Mast 2005, 739).[98] Few of these mention hallucinations. In those that do, any consideration of a relationship between mental imagery and hallucinations is minimal. For example, when discussing the role of mental imagery in psychopathology Roger Ng and colleagues (2013, 367) make a passing reference to the possibility that a "deficit in deliberate mental imagery of past memories and future events" may contribute to the various positive symptoms of schizophrenia.

[98] For an important exception, see (Lawson and Lacey 2013, 423).

In the second case, hallucinations in the non-clinical population are rarely discussed in relation to mental imagery; even when mental imagery is mentioned in this context, it is treated as a distinct concept. Indeed, in *A comprehensive review of auditory verbal hallucinations: lifetime prevalence, correlates and mechanisms in healthy and clinical individuals* the single passing mention of mental imagery is in relation to the unpopular theoretical possibility that imagery is predictive of the onset of hallucinations (de Leede-Smith and Barkus 2013, 14).

Given that the concepts of mental imagery and hallucinations are each used without clarifying how the SLMP in question differs from any other, the independent uses of these two concepts appear relatively stable (even if unjustifiably so). Indeed, even on the rare occasion when neuroimaging research into mental imagery and hallucinations are considered side-by-side, these conceptualisations of functional and dysfunctional experiences of SLMP are still treated as distinct. For example, sometimes the regions of localised neural activity found to correlate with ordinary experiences of mental imagery have been recognised as sharing considerable overlap with to those regions implicated in the dysfunction responsible for hallucinatory experiences (Allen et al. 2008; Hill and Linden 2013, 35).

If both mental imagery and hallucinations conceptualise different forms of SLMP, then some overlap in neurophysiological processes is to be expected and does not preclude unique neurophysiological mechanisms being identified for SLMP conceptualised as mental imagery and hallucinations respectively. Although yet to be fully realised, this possibility contributes to explanations for the recognised overlap.[99] For example, one explanation for this overlap is that mental imagery and hallucinations share underlying bottom-up sensory processes while their top-down regulatory processes diverge to produce two distinct phenomena (e.g., Grossberg 2002; Mast 2005). Other speculative explanations include, conversely, that there

[99] For some other examples and their associated debates see: (Kelly Maria Johanna Diederen, Van Lutterveld, and Sommer 2012; Linden et al. 2011; Shine et al. 2015).

is some dysfunction of 'bottom-up' perceptual processing that might either lead to the misattribution of memories or to impaired abilities to recognise genuine perceptual stimuli (Badcock and Hugdahl 2012b, 320–21). As such, there remains no consensus regarding the involvement in hallucinations of any brain region that is not also implicated in the experience of mental imagery (Hill and Linden 2013, 33).[100] Nonetheless, the experiences of SLMP conceptualised as mental imagery and hallucinations are considered distinct. For example, Shine et al. (2015, 5–6) emphasise that despite overlap in their neurobiological mechanisms hallucinations and imagery differ (particularly in regard to volitional control) such that they can be treated as distinct phenomena.

As such, even when overlapping SLMP-neuroanatomical-correlates are discussed, the possibility that mental imagery and hallucinations each have unique SLMP-neuroanatomical-correlates remains the focus. Indeed, it is through the identification of SLMP-neuroanatomical-correlates using the concepts of either mental imagery or hallucinations that neurophysiological mechanisms are often proposed to explain their respective roles in neurocognitive processes. Therefore, drawing these points together, the concepts of mental imagery and hallucinations can each be understood as bodies of knowledge that, by characterising SLMP as either ordinary or abnormal, individuate certain classes of SLMP from other classes of SLMP for investigating functional or dysfunctional neurocognitive processes respectively.

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[100] One response to this inability to identify distinct regions responsible for the pathology of hallucinations (as compared to mental imagery) has been to investigate the relative timing of activation in these shared areas (Hill and Linden 2013, 34–35). New approaches may produce the elusive distinction between the neurocognitive processes of mental imagery and hallucinations. However, in the meantime, they exist alongside existing approaches and face many of the same challenges.

3.5 Characterising Concepts for Independent Use in Neuroimaging Experiments

Despite their questionable value, the typical characterisations of those experiences of SLMP conceptualised as either mental imagery or hallucinations continues to be evident within the criss-crossing uses of each concept for differentiating between ordinary and abnormal experiences of SLMP in different contexts. Furthermore, these characteristics each function as an unnecessary yet, at times, sufficient criterion for determining when experiences of SLMP are hallucinations (and if, so, whether they are pathological or not) or when they are mental imagery (and if so, whether they are ordinary or not). However, as discussed earlier, none of these characteristics actually distinguish between the concepts of mental imagery and hallucinations sufficiently for use in investigating the role of SLMP in neurocognitive function and dysfunction respectively.

Furthermore, although these characteristics have rarely been used as complete sets, the relationships between the contrasting types of characteristics remain conceptually entangled. For example, in those circumstances when SLMP are not consistent with the typical characterisation of mental imagery, this concept is instead distinguished from hallucination by the criteria that the subject does not misattribute the image to an external source and/or has insight that the confusing image is self-produced (e.g. M. Martin and Williams 1990, 268; Ng, Krans, and Holmes 2013, 366). This is particularly evident when the concept of mental imagery is used to include involuntary SLMP. For example, spontaneous (involuntarily generated) mental images have been described as an important aspect of ordinary memory processes which are more useful when amendable to volitional control (Brewin et al. 2010, 211; Richardson 1969, 43). Likewise, when experiences conceptualised as hallucinations differ from one or more of the paradigmatic criteria, other typical characteristics fill the void. This type of flexibility is evident within the shift away from perceptual similarity of hallucinations towards an interest in the role of metacognitive dysfunction (e.g., Varese and

Larøi 2013, 154). Similarly, despite the increasing interest in both the negative content and the role of emotional-valence during hallucinatory experiences, the proposed underlying mechanisms continue to focus on the dysfunctional control and/or regulation of ordinary internal events (e.g., Badcock and Hugdahl 2012b).

This flexibility highlights some of the problems with relying on distinctions between the concepts of mental imagery and hallucinations based on any of their typical characteristics. As illustrated earlier (Tables 2 and 3), none of these characteristics predict whether a given experience of SLMP will be experienced as distressing, benign, or useful. In addition, the characteristics reported during actual experiences of SLMP conceptualised as either mental imagery or hallucinations also fail to support the inverse sets of typical characteristics (Table 4). Once again, maintaining the colour-scheme from earlier tables, this comparison highlights the ambiguous boundary between those SLMP conceptualised as either mental imagery or hallucinations. In short, none of these characteristics suffice as an explanation for why some SLMP resemble perception (mental imagery) while others are experienced with the compelling sensation of perception (hallucinations).

Table 4: Variable characteristics reported for either mental Imagery or hallucinations

	Typical Mental Imagery	Reported Mental Imagery	Reported Hallucinations	Typical Hallucinations
Perceptual Similarity	Low	Variable	Variable	High
Location	Internal	Variable	Variable	External
Volition	Voluntary	Variable	Involuntary	Involuntary
Control	Manipulable	Variable	Variable	Uncontrolled
Duration	Fleeting	Variable	Variable	Persistent
Attribution	Self	Self	Variable	Others
Insight	Maintained	Maintained	Variable	Lack of Insight
Valence	Positive	Variable	Variable	Negative
Impact	Benign	Variable	Variable	Disruptive
Content	Useful	Variable	Variable	Unwanted
Frequency	Variable	Variable	Variable	Frequent

Drawing these points together, it becomes clear that using the concept of mental imagery for ordinary SLMP and the concept of hallucinations for abnormal SLMP may not actually individuate those SLMP experienced as useful/benign or distressing respectively. Extrapolating from this, none of these characteristics can be regarded as sufficient for differentiating between functional and dysfunctional experiences of SLMP.

To conclude, I will summarise the key point from this chapter: that the inversely related typical characterisations of mental imagery and hallucinations are insufficient for individuating discrete types of SLMP and, as such, fail to justify the uses of these concepts for investigating the roles SLMP in neurocognitive function and dysfunction respectively. At this point, it is worth reiterating that this conceptual ambiguity is not, in and of itself, an insurmountable problem. Indeed, appending differentiating characteristics to the definitions of mental imagery and hallucinations has helped to delineate specific experiences of SLMP from various other experiences of SLMP for further investigating these specific experiences. Furthermore, as mentioned earlier, questions about how well the concepts of mental imagery and hallucinations refer to mutually-exclusive types of SLMP are beyond the present scope. For the present purposes, the difficulty in distinguishing between the concepts of hallucinations and mental imagery is worth investigating more because it offers a way of examining the role of these concepts in experiments that investigate SLMP.

Given this, recall that these two ambiguously delineated concepts are each used independently of the other to isolate specific instances of SLMP for further study. This point draws attention back to the overlap reported in the changes in neurophysiological activity identified during mental imagery and hallucinatory experiences (Allen et al. 2008; Hill and Linden 2013, 34–35). In the present context, the key point is that the overlap in SLMP-neuroanatomical-correlates are routinely explained away by the possibility that some of the neurophysiological processes are similar in mental imagery and hallucinations while other neurophysiological processes are unique to just one experience or the other. Given these explanations, the ambiguity between the typical characteristics for the concepts of mental imagery and hallucinations becomes an intriguing problem. Indeed, when positioned within the theoretical approach offered in Chapter Two, these explanations raise the following question: what are the implications of using the interdependent concepts of mental imagery or hallucinations independently of the other in neuroimaging investigations into the neurophysiological processes underlying either functional or dysfunctional neurocognitive processes?

One way to answer this question is to examine the uses of the concept of either mental imagery or hallucinations in neuroimaging experiments that, when compared, can be seen to have reported overlapping SLMP-neuroanatomical-correlates in support of disconnected knowledge-claims about the role of these SLMP-neuroanatomical-correlates in either functional or dysfunctional neurocognitive processes. This will be the focus in Chapters Five through Seven. However, as discussed earlier, it is also important to determine how these current independent uses of the concepts of mental imagery and hallucinations came to be as they are.

To this end, in the following chapter I will offer an account of some of the historical conditions within which these specific characterisations of functional and dysfunctional forms of SLMP came to distinguish between the concepts of mental imagery and hallucinations. In doing so, I aim to draw attention to the mediating-role associations about SLMP that are enshrined in the inverse relationship of 'typical characteristics' that, as detailed above, fail to explain the independent uses of the concepts of mental imagery and hallucinations in current neuroimaging practices. To foreshadow my later argument, it is this series of associations that structures the independent uses of the concepts of mental imagery and hallucinations; an independence that supports their uses as discrete tools for pursuing diverging goals (of investigating the role of SLMP in functional and dysfunctional neurocognitive processes respectively).

4 Mental Imagery, Hallucinations, and their Historical Connections

Mental imagery provides the standard concept for neuroimaging investigations into the functions of ordinary SLMP. Meanwhile, the dominant concept in neuroimaging investigations into the pathology of dysfunctional SLMP is hallucinations. However, as detailed in the previous chapter, the independent uses of these two concepts sit at odds with their inversely related typical characteristics. Keeping in mind the theoretical approach developed in Chapter Two, this conceptual ambiguity raises the following question: how did the inversely characterised concepts of mental imagery and hallucinations come to be used as independent tools for investigating discrete epistemic goals?

To answer this question, I will explore how the concepts of mental imagery and hallucinations each developed as independent tools for pursuing specific goals in neuroimaging experiments. My historiographical approach here is narrow: I will leave aside the wide range of social, political, economic, and technical contexts required for examining the inter-related dynamics of the various scientific practices that use the concepts of mental imagery and hallucinations.[101] Instead, I will focus on highlighting how the uses of the concepts of mental imagery and hallucinations as independent tools in neuroimaging experiments were forged from a shared philosophical view of SLMP.[102]

I will begin this historical account by outlining philosophical views of SLMP that prefigured the interdependent characterisation of the scientific concepts of mental imagery

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[101] As noted earlier, the value of this tool-centred historical account is best understood as partial; requiring integration with insights from other historiographical approaches to contribute to the broader picture of the dynamics of scientific practice. For example, experimental uses of each concept could be considered in relation to other specialised histories and/or by examining broader the scope to examine societal reasoning-style 'organising concepts' such as *pathology* (Hacking 2002; Sciortino 2016).

[102] In a recent publication (E. T. Smith 2018) I present a shorter account of this research to support the related argument that using mental imagery and hallucinations as independent tools for pursing discrete goals, simultaneously reflects and obscures that historical interdependence.

and hallucinations. This *mediator-view of SLMP* positions ordinary SLMP as desirable because they are required to mediate between unruly sensations and the reasoned judgement of abstract thought; and abnormal SMLP as undesirable because they occur when these judgements fail (due to physical or mental dysfunction).[103] Building on this, I will then explore a selection of nineteenth- and twentieth-century debates over the value of the concepts of mental imagery and hallucinations (as each was distinguished from other conceptualisations of SLMP).[104] In the case of mental imagery, I will discuss the early questionnaires reporting individual variability in mental imagery; challenges from the imageless-thought debates at the turn of the century; the thirty year 'fallow-period' of imagery research; interest in abnormal mental imagery; and the revival of research into ordinary mental imagery. Complementing this, I will then explore a selection of historical episodes relevant to the process of uniting the term hallucination with the concept that some types of SLMP are symptomatic of brain dysfunction; a type of dysfunction contributing to multiple mental disorders.

In each case, I will outline how a specific series of associations were inherited from the strong mediator-views of the nineteenth-century. As evident in the typical characterisations of each concept, these *mediating-role associations* for SLMP became routine; implicitly carried along by the uses of each concept long after the theoretical justifications for these entrenched associations were abandoned.[105]

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[103] For 'strong' and 'weak' varieties of these *mediator-views (of SLMP)*, see Appendix 1 (Annotated Glossary).

[104] My focus on published sources here provides important context for my later analysis of the uses of these concepts within published accounts of neuroimaging experiments (see Chapter 5). However, it would be interesting to compare these published debates with an examination of any unpublished records detailing the uses of these concepts in experimental practices.

[105] I will discuss this more detail later – also see, Appendix 1 (Annotated Glossary).

Finally, I will illustrate how this examination of these intersecting historical trajectories relate to the theoretical approach I developed in Chapter Two. To briefly recap, this approach rests on the suggestion that the uses of concepts as experimental tools can be structured by disciplined routines of conceptual associations that contribute to the knowledge generated by experiments for investigating specific epistemic goals. This question can now be rephrased for the specific concepts of mental imagery and hallucinations as introduced in Chapter Three: how do bodies of knowledge that individuate an experience of SLMP as either ordinary (mental imagery) or undesirable (hallucinations) contribute to investigations that seek to understand the role of SLMP in the functions and dysfunctions of neurocognitive processes? In this chapter I seek to provide one element of an answer to this question. To this end, I will demonstrate that these ambiguous conceptual distinctions provided space within which the structured uses of these two interdependent concepts came to be used independently of each other for investigating discrete epistemic goals.[106]

4.1 Philosophical Accounts of Sensory-like Mental Phenomena

Philosophical accounts of both functional and dysfunctional SLMP pre-date their conceptualisations as mental imagery and hallucinations respectively.[107] To illustrate these early descriptions of SLMP, I will draw primarily on existing accounts of the philosophical development of contemporary understandings of mental imagery (Bower 1984; Brann 1991; Casey 2000; Cocking 1991; Paivio 1970; Roeckelein 2004; Waller et al. 2012) and hallucinations (André Aleman and Larøi 2008; Berrios and Marková 2012; Peyroux and

[106] Note that I am interested in questions that are in addition to (not instead of) those on how other factors, such as disciplinary divides, contribute to these conceptual development processes.

[107] For a discussion of the challenges and value of comparing ancient accounts of SLMP with current conceptualisations such as hallucinations, see: (Harris 2013, 288–89).

Franck 2013; T R Sarbin and Juhasz 1967).[108] By considering these existing accounts together, I seek to highlight how the useful role of ordinary SLMP in thought has been contrasted with the compellingly real 'visions' of divinity or madness. In doing so, my aim is to illustrate the persistence of a 'mediator view' of SLMP within which ordinary SLMP (that resemble perception) were distinguished from those SLMP that can lead to confusion (due to their compelling sense of perception).

I will begin by sketching some key philosophical contributions to the mediator-view of SLMP; a view that provided the knowledge-context for investigating SLMP at the beginning of the nineteenth-century. Following others, I will begin this story with Plato's notion of *phantasia;* an inner awareness of sensory information provided by the world (Brann 1991, 39–40; Cocking 1991, 12–13, 20). As a faculty that can include mental replicas of perception, *phantasia* aid a rational image-recognition processes that – subservient to abstract knowledge and rational judgement – tacitly affirm or deny the truth of a perception (Brann 1991, 41; Cocking 1991, 25, 53). When taking up Plato's *phantasia,* Aristotle agreed that images must remain subordinate to abstract thought (Cocking 1991, 25, 53). However, Aristotle rejected the view that images merely serve the judgement of perception; reconfiguring *phantasia* into a function that allowed absent sensations to be properly presented to the intellect (Brann 1991, 41–42). To this end, Aristotle described *phantasma* as novel mental experiences "like sensuous contents except they contain no matter" (Cocking 1991, 19–20).[109] These *phantasma* provided both a mental object and a mental representation that copied an absent object (Brann 1991, 44).

[108] In addition to these I have drawn on descriptions of SLMP in historical accounts of mental disorders (Berrios 1996; Harris 2013; Kales, Kales, and Vela-Bueno 1990), and various abandoned concepts, such as dysfunctional imagination (McMahon 1976).

[109] For the original quote, see Aristotle's *De Anima* (1984, 432a).

Aristotle's view provided a foundational understanding of images as depicting the sensory experience, rather than mere descriptions of sensory experience (Roeckelein 2004, 146). In further contrast to the limited role Plato gave to images, Aristotle initiated a tradition where "images became the *essential* intermediary between perception and conception" (Cocking 1991, 19 original emphasis). For instance, Aristotle proposed that *phantasma* needed to be manipulated in order that ideas could go beyond the particular experience via a process of abstraction (Cocking 1991, 19–20; Roeckelein 2004, 146).

In describing *phantasma*, Aristotle also drew a distinction between the active construction of images (mediators between perception and thought) and the passive images confused with divine messages (attributed to bodily dysfunctions) (Cocking 1991, 53, 270). This view was consistent with Hippocrates earlier attribution of divine visions to physical disturbances of certain bodily states (Mora 2008, 201; Peyroux and Franck 2013, 6). In line with this distinction between active (voluntary) and passive (involuntary) SLMP, Aristotle recommended that imagery be regulated in order to balance behaviour (Waller et al. 2012, 292).

In this way, Aristotle placed images as a mid-point in an existing hierarchy: as a fragile mediating point between base physical sensations and the goal of reasoned judgement thought to be required for abstract thought (Cocking 1991, 24). For Aristotle, balancing behaviour included managing those emotions stimulated by the desirability or aversion of imagined objects (McMahon 1976, 179). This notion was developed by the Stoics into an influential model of humoral balance. In this model, images physically impact the body/soul in either detrimental or therapeutic ways depending on their vividness and persistence (McMahon 1976, 181). For example, detrimental outcomes occur when vivid and persistence images distort the perception of reality (McMahon 1976, 181). Similarly, although rejecting Aristotle's interest in emotions, Galen also drew on the Hippocratic approach. In doing so, Galen developed a theory of insanity that included errors of imagination due to the physical disturbance of excessive black bile (T R Sarbin and Juhasz 1967, 344).[110]

From these foundations in Classical Greek philosophy, accounts of SLMP followed multiple convoluted paths during the Middle Ages (Cocking 1991). One trajectory included the preservation and further development of the earlier classical approaches by Arabic philosophers (Kales, Kales, and Vela-Bueno 1990, 9–10).[111] Meanwhile, Christian doctrines shifted the focus towards determining the *source* of SLMP: leading to attempts at articulating the specific characteristics that differentiate divine-visions from occult-visions. For example in the fourth-century, St. Augustine distinguished between perception (located in time and space), images (located in time but not space), and intellectual apprehension of concepts (located in neither time nor space) to suggest that occult visions are confused with divine visions when images occur in both time and space like perception (Theodore R. Sarbin and Juhasz 1970, 340). This approach once again positioned bodily sensation as subordinate to abstract thought; with a progression from bodily-sensations to intellectual abstraction regarded as a progression towards reliability (T R Sarbin and Juhasz 1967, 341).

There were also other attempts to determine the source of SLMP. During the thirteenth-century St Thomas Aquinas positioned divine visions as rare events that needed to be confirmed by the church; all other involuntary SLMP were unnatural (T R Sarbin and Juhasz 1967, 341). In addition, incorporating the works of Hippocrates, Galen, and Arabic physicians, Aquinas described various disturbing mental experiences – including those redolent of hallucinations – as exclusively somatic diseases (Kales, Kales, and Vela-Bueno 1990, 10; Mora 2008, 208–9). In contrast to these, Aquinas maintained Aristotle's view that

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110 Although a broader debate, it is worth noting that questions about insanity/madness often made no distinction between SLMP experienced with a compelling sense of perception and those experiences redolent of delusional beliefs.

111 Also see (Pormann 2013; Wolfson 1935).

voluntary images provide a necessary intermediary stage between perception and thought (Brann 1991, 64). For example, Aquinas described imagination as the faculty that stored *phantasms* – a sense-image of extended spatial likeness to prior sensations – for illumination by the intellect during a process of abstraction (Brann 1991, 62–64). Consistent with this strong mediator-view, this description emphasised that the manipulation and use of these stored sensations relied on the reasoning power of abstract thought (Cocking 1991, 151).

Alongside their vital role in mediating thought, faculties such as imagination and memory were also implicated in attempts to locate madness in the body while absolving the soul of fault. For example, prior to the seventeenth century madness was often conceived as a two-fold process involving damage to the body that directly impaired imagination and memory, and failures in the higher functions of judgement and reason that occurred as an indirect outcome of the impaired imagination/memory (Suzuki 1995). In line with the mediating-view, this view positioned "becoming mad [as] the creation of a false image, which was represented by the lower faculties to the higher ones…" (Suzuki 1995, 421).

The influences of strong mediator-views are also evident within debates over the nature of ideas between the seventeenth and nineteenth centuries (N. J. Thomas 2006, 1). For example, Thomas Hobbes described sense-images as distinct from non-sensory thought (Roeckelein 2004, 147–48). Even so, Hobbes still considered images to contribute to thought: imagination providing a 'decaying sense' that becomes memory once the sensation has decayed even more (Faw 2009, 5). Similarly, despite the influence of Descartes' mind-body dualism, madness was still being positioned as due to the power of a false image (triggered by bodily disorder) to deceive the mind through the abnormally high degree of perceptual similarity (Suzuki 1995, 424–26).

An even more explicit development of the Aristotelian account of imagery can be found in the works of John Locke and George Berkeley (Roeckelein 2004, 148; Faw 2009, 6). For example, Locke sought to distinguish between sensory-experience and perceptual-judgement – with the images of sensation only as reliable as the ability to correctly attribute them to perceptual stimuli (Suzuki 1995, 426; 431). Distinctions such as these played crucial roles in the eighteenth-century debates over whether the madness was a passive response to aberrant sensations of the body or a failing of the injudicious mind allowing itself to be misled by sensation (Suzuki 1995, 426; 431). I will discuss various iterations of these types of debate as they relate to hallucinations later. For now, allow me to turn to David Hume's critical development of the work of Locke and Berkeley in the eighteenth century.

Hume described a complex relationship between impressions (sensations and reflected sensations) and ideas (both simple and complex). This relationship can be summarised in three points: that every simple idea resembles a corresponding sensory-based impression; that all complex ideas are formed by combining simple ideas; and that not all complex ideas directly resemble a specific impression (Hume 2003, pts 1.1, 1.7). Crucial to this relationship was Hume's (2003, 1.2) view that impressions "are copied by the memory and imagination, and become ideas".

This echoes earlier mediator-views of SLMP. For example, Locke (1894, 104, 108–10) also described different types of ideas, including simple ideas (requiring an *impression* of perception), complex ideas (formed through *association* of simple sensory-bound ideas), and abstract general ideas (obtained by *abstraction* from the association of simple ideas). In line with even earlier accounts, Hume positioned abnormal SLMP as a disruption of the judgement processes required to rearrange images into the complex ideas required for abstract thought.[112] To this end, Hume (2003, pt. 1.3) was careful to distinguish between the

112 It is important to recall the nuanced distinctions between complex ideas and abstract ideas mentioned earlier. Given the nuance within the empirist tradition are beyond the present scope, I simply seek to emphaises that process of associating simple ideas into complex ideas was a valuable step in forming the general ideas of abstract thought.

processes of memory and imagination: memory provide vivacious copies of perception that force themselves on the mind; imagination relies on faint, languid, and transitory copies of perception that are able to be manipulated into novel combinations. Of these, Hume (2003, pt. 1.4) positioned the fainter, easily manipulable ideas of imagination as playing the critical role in abstract thought where, guided by a gentle dominating force, a processes of association re-arranges sense-images in order to unify simple ideas into complex ideas. Furthermore, in both memory and imagination the 'copy' was positioned as able to be readily judged, by a reasonable person, as distinct from the original perception (Dauer 1999, 85–87; Hume 2003, pt. 1.1). Only during fever, madness, and 'violent emotions' do wakeful image-based ideas achieve a level of similarity with perceptual impressions such that judgement can fail (Hume 2003, 1.1). Once again, this echoes earlier views. For example, Locke (1894, 105) argues that 'idiots and madmen' are unable to make use of language or reason because they are unable to "distinguish, compare, and abstract".

Hume's account of memory and imaginations as 'copied perceptions' – with the latter critical for, yet subservient to, abstract thought – provided the dominant view of mental imagery at the beginning of the nineteenth-century (Bower 1984; Roeckelein 2004, 149; Faw 2009, 6). At the same time, the importance that Hume placed on the role of judgement in guiding the association of simple-ideas into complex ideas influenced medical approaches to madness in the late eighteenth century (Suzuki 1995, 432).

This wide-ranging influence of Hume's mediator-view of SLMP suggests that the series of associations that I have traced through various philosophical accounts of SLMP were adopted into scientific and medical practices. I will return to this point later. For now, allow me to summarise the series of associations I see being carried along by the 'mediator-view'. The first step is the view that ordinary SLMP resemble perception for the purposes of memory and imagination. Following from this, is the view that these copied perceptions play a mediating role between bodily sensations and – via complex ideas – the ultimate goal of abstract thought. However, to safely mediate in this way, ordinary SLMP must be active and voluntary or, if passive, controlled by rational judgement. Therefore, by extension, undesirable SLMP (such as unsanctioned-visions, disturbed imaginations, and hallucinations) can be confused with perceptions due to physical dysfunction that somehow disrupts the mediating role of ordinary SLMP.

In this way, the mediator-view associations operate on the expectation of an inverse relationship between the degree to which ordinary and abnormal SLMP are experienced 'as if' perceived. As I discuss in a moment, it is these expectations that provide the point of intersection between the later concepts of mental imagery and hallucinations.

4.2 Mental Imagery as Neurocognitive Function

The historical contexts within which the concept of mental imagery became central to theories of memory and imagination have been well documented (Bower 1984; Denis 2012; Denis, Engelkamp, and Richardson 1988; Holt 1964; MacKisack et al. 2016). As sketched in the previous section, this includes a long history of philosophical theories positioning images as a mediator (of variable importance) between perception and abstract thought. In addition, imagery has since been positioned as contributing to a wider range of high-level cognitive processes (e.g., Brann 1991, 229; J. Pearson, Clifford, and Tong 2008; Posner 1997, 95). Therefore, in this section I will focus on highlighting some historical episodes that help to contextualise the current uses of mental imagery (as a conceptualisation of SLMP that are experienced as resembling perception) to investigate a wide range of neurocognitive processes. To this end, in addition to existing historical accounts, I will draw directly on some scientific accounts of mental imagery published during the nineteenth and twentieth centuries.[113]

During the nineteenth-century, mental imagery was considered a legitimate mental activity for investigating with introspective psychological methods (Brann 1991, 230; Holt 1964, 256; Paivio 1970, 385). In one famous example, Francis Galton (1883, 89–91) asked subjects to recall seeing their breakfast table and reported a wide range of responses: from "[seeing] all the objects in my mental picture… as bright as the actual scene"; to being able to look "down the table and see the different things distinctly, but not the whole table at once"; or simply recalling "only a general idea of a very uncertain kind" (Galton 1883, 89–91).[114] Although not the first, Galton's imagery-questionnaires were influential in the trend towards quantifying types of imagery experiences within experimental psychology (MacKisack et al. 2016). To this end, Galton's questionnaire was later developed, with individual subjects asked to respond to sets of questions about mental imagery, after which, reported qualities – such as the vividness, persistency, and controllability of an image – were analysed across multiple subjects (Angell 1910, 68).

By the early twentieth-century the classic tendency to attribute a mediating-role of SLMP had been subtly modified. Individual differences in mental imagery became of increasing interest and, rather than being crucial to all thought, SLMP were repositioned as an element of intellectual development that should be subordinate to abstract thought by adulthood. For example, George H. Betts (1909) emphasised individual variability of imagery

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113 Including analysis of specific debates as published within the Psychological Bulletin, the Psychological Review, The American Journal of Psychology, and The Journal of Philosophy, Psychology and Scientific Methods.

114 For discussions on the emphasis on memory-imagery in the nineteenth-century, see (Perky 1910, 424; Theodore R. Sarbin and Juhasz 1970, 67).

experiences while simultaneously dismissing *reliance* on imagery as childlike.[115] In terms of variability, Betts (1909, 40–41) reported that in experiments of voluntary imagery in all modalities "16% [of subjects] report images perfectly clearly and in general as vivid as the actual experience… while 9% report no images present at all".

Given these diverse individual experiences, Betts (1909, 98) concluded by positioning imagery as one mental element among many. However, for Betts, imagery was also the element that "may often drop out altogether [in adult thinking] without in any way hampering the efficiency of the other mental elements". This apparent tension between findings of the majority of experiences involving imagery and a conclusion that imagery is unnecessary for thought are bridged by Bett's (1909, 93) speculations that:

> "[children] should employ much more imagery than adults [because the] child's mental world is relatively a world of percepts, covering the range of all the senses. Each percept is the basis for an image, which comes to supplement the percept [taking on] the same meanings as the percepts in a degree, and sometimes become almost as real. But gradually the meanings come to inhere more in the relations of the objects than in the objects themselves, and imagery gradually loses its function except where the meaning continues to reside chiefly in the object itself as such"

Rather than simple image-based ideas combining to form complex abstract ideas, simple children relied on imagery yet grew up into adults with complex abstract thoughts. Following this modification, the classic mediating position of SLMP was explicitly rejected during the imageless-thought debates of the early twentieth-century.

These debates grew out of this notion that imagery was not relevant to thought at all (Brann 1991, 230; Stephen M. Kosslyn, Ganis, and Thompson 2010, 3). On one side of this

[115] In addition, Betts (1909, 46–47) criticised the emphasis on visual imagery; inference of imagery abilities from preferences in perceptual modality; and the conflation of imagery differences with differing intellectual pursuits.

debate were the defenders of the classic-view; arguing that images necessarily mediate between perception and conscious thought. For example, Angell (1911, 299, 305–12) argued that those who dismissed the critical role of imagery in thought were simply ineffective at introspection (rejecting the possibility that there are radically different types of mental organisation). On the other side of the debate were the proponents of imageless-thought. For example, Robert S. Woodworth (1915, 4, 15) argued that, "all recall is of facts previously noted, freed from the concrete setting in which they occurred when noted". As part of this argument, Woodworth employed a similarly obstinate strategy to that of Angell. For example, Woodworth (1915, 14–22) allowed that images are sometimes included in the 'web of thinking', yet argued that introspective accounts of highly-vivid imagery were merely a "revival of personal attitude and emotional value", and that a test of incidental recall would reveal these images as inaccurate. At the same time, Woodworth (1915, 18–22) supported his argument that analytic recall is superior to imagery-based recall by detailing an introspective account of his own imageless thoughts.

The range of the imageless-thought debates can be illustrated by surveying all the articles relating to mental imagery published within the first twenty-five volumes of the *Psychological Review* (1894-1918). During this time, four authors explicitly advocated for imageless-thought (Moore 1915, 1917; Pillsbury 1908; Stanley 1897; Woodworth 1915) while three authors defended the critical role of imagery in conscious thought (Angell 1911; Colvin 1906, 1908; Lay 1903a, 1903b). In addition, two authors offered intermediate views: S.F. MacLennan (1902) argued that images always furnish the basis of ideas, the meanings of which form in a synthetic reference system; while E.C. Tolman (1917) argued that meaning is distinct from, yet dependent upon, imagery.[116] A further six authors discussed the functions of mental

[116] For variations within each side of the *imageless-thought debates*, see Appendix 1 (Annotated Glossary).

imagery without explicitly weighing into the imageless-thought debate (Alexander 1904; Armstrong 1894; Downey 1901; French 1902; Kuhlmann 1906; Langfeld 1916). However, although not engaging directly, these authors nonetheless aligned themselves with elements of the imageless-thought position: noting that imagery abilities decrease with age (Armstrong 1894; Langfeld 1916; Stetson 1896); that reliance on imagery decreases as skill in abstract thinking increases (Alexander 1904; Armstrong 1894; Kuhlmann 1906; Langfeld 1916); and that imagery is an impractical and emotional reaction (Kuhlmann 1906; Langfeld 1916).

As in imagery debates more generally, arguments on both sides "sprung from the same philosophical assumption that one's own mental 'intuition' is representative of *homo sapiens mentalis*" (Faw 2009, 7–8).[117] This reliance on personal experiences for theorising about the mental experiences of *all* humans has had far-reaching impacts.[118] For example, these imageless-thought debates contributed to broader debates over the use of introspective methods in psychology (Holt 1964, 256).[119] These broader debates eventually culminated in the rejection of introspective methods for describing and explaining mental processes (such as memory and thinking) in favour of analysing behaviours such as learning and problem-solving (Holt 1964, 259). For example, the behaviourist and imageless-thought advocate John Watson ([1913] 1994, 250) argued that investigations of mental states and imagery, should be discarded in favour of analysing stimulus and response or habit formation. In many ways, the mediating role between perception and thought previously attributed to images came to

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117 Some scholars did gesture beyond this polarisation of intuitions (albeit briefly). For example, see F.C. French's (1902, 51) footnote that, while he himself did not experience auditory imagery, he did not doubt that others did.

118 For example, the differing introspective understandings of individual imaging experiences contributes to literary-theoretical debates about aesthetics in the nineteenth century, see: (MacKisack 2016).

119 For a discussion of the quasi-disappearance of introspection in psychology see (Bitbol and Petitmengin 2015). Also see (U. Feest 2014) for a discussion of some of the broader debates about the role of introspection (and self-reports) in the history of psychology.

be replaced by verbal and gestural responses within behavioural psychology (Paivio 1969, 242).[120] For example, Watson famously argued that all thought is merely a process of talking to ourselves (Faw 2009, 8–9).

By the 1930s, when imagery was discussed at all it was to emphasise that it should be subordinate to reasoned judgement by adulthood (e.g. Dumville 1931, 85; Edgell 1936, 123). A striking illustration of this view is evident in the debates over *eidetic imagery*: a notion developed around the finding, by Erich Jaensch's research group, that some children could describe imagery of remembered objects as if the object were perceived (Allport 1924; Edgell 1936, 124). Although persistent and vivid, eidetic images could be experienced as either 'inside the head' or projected into external perceptual space (Edgell 1936, 124; Richardson 1969, 31; Ahsen 1977, 6). In short, these subjects acted as if SLMP were located within perceptual space while maintaining insight that these SLMP were not perceptions (Richardson 1983, 23–26).

Multiple conflicting explanations were proposed for the relationship between eidetic images and other SLMP. Eidetic imagery was proposed to be a unique type of SLMP, as well as a form of ordinary imagery that simply differed by degree (being more percept-like) (C. R. Gray and Gummerman 1975, 383). In both approaches, the high degree of perceptual similarity was explained as useful during the developmental stages of childhood; eventually being replaced by abstract thought in normal adults (e.g., Allport 1924, 115–19). In this way, a high degree of perceptual similarity in imagery-like experiences was characterised as an undesirable intermediate form of SLMP (neither ordinary nor pathological). Given the high degree of vividness and external location, other characteristics distinguished these childhood SLMP from hallucinations; notably, insight (Brann 1991, 293) and degree of volitional

[120] Exceptions can be found in research on *types of mental imagery* however these contributed more to education theory than imagery research as such – see Appendix 1 (Annotated Glossary).

control (Faw 2009, 16). These relationships between mental imagery and eidetic imagery on the one hand, and between eidetic imagery and hallucinations on the other, reflects how the classic mediating-view of SLMP had slowly been modified such that SLMP had been repositioned as mediating between the perceptual-reliance of childhood thought and the abstract-thinking of healthy adults.

With mental imagery dismissed as a remnant of childhood thinking, there was a thirty-year 'fallow' period during which few experimental studies used the concept of mental imagery (Holt 1964, 257; Hebb 1968, 737; S. M. Kosslyn, Behrmann, and Jeannerod 1995, 1136).[121] The few experimental studies published on mental imagery during this time focused on environmental conditioning or objectively testable aspects of imagery experience such as the as respiration rhythms (e.g., Golla, Hutton, and Walter 1943; Russell 1920; Schilder 1933).

This small field of interest in the physiological mechanisms of mental imagery was aided in the 1950s by advances in research techniques, such as electroencephalography (EEG) and direct brain stimulation (Holt 1964, 258–59). This research into the physiological correlates of imagery provided important groundwork for later studies (K. White, Sheehan, and Ashton 1977, 161–62). However, it took some compelling demonstrations that imagery experiences could influence behaviour to shift the view of mental imagery as an epiphenomenal curiosity into a legitimate topic for scientific investigation (Cooper 1995, 1575).[122]

Within this context of experimental psychology, individual variance was regarded as an 'error variance' that should be reduced by any means possible (Cronbach 1957, 674). As such, legitimacy for the concept of mental imagery required careful characterisation: images were ordinary volitional experiences shared with minimal variation by all healthy individuals. To

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[121] This *fallow period of mental imagery research* has been attributed to a range of factors – see the subsection of *Mental Imagery* in Appendix 1 (Annotated Glossary).

[122] For example, see O. Hobart Mower's (1977) personal account of the slow process of validating mental imagery as a concept worthy of study within psychology.

establish these credentials, mental imagery was frequently contrasted with conscious perception, illusions, dreams, and abnormal mental experiences such as hallucinations. For example, J. Rossett (1939, 262) differentiated between thought, imagery, and hallucination based on the following change in characteristics: diminished orientation in the present, increased inaccuracy, and increased vividness. Similarly, P.L. Short (1953, 38) argued that the active construction of images helped to distinguish these from the passive reactions to sensations in hallucinations, illusions, and perceptions. These types of declarations help to explain why ordinary mental images were considered readily distinguishable from perception.

Despite this groundwork, it was not until the late 1960s that scientific interest in the cognitive function of everyday mental imagery emerged as a field in its own right (Holt 1964; S. M. Kosslyn, Behrmann, and Jeannerod 1995). This renewed interest spread across a range of disciplinary approaches (Hebb 1968, 741; Paivio 1969, 242). However, this revival is typically attributed to the shift away from the behaviourism and towards the testable theoretical models of cognitive psychology (Holt 1964, 259–60; Paivio 1969, 242; MacKisack et al. 2016).[123] The rise of cognitive psychology provided the space for mental processes such as thinking and memory (and the endogenous experiences of mental imagery these might involve) to once again become a topic of scientific interest (Holt 1964, 259).

Within this space, mental imagery research prioritised correlating experiences of SLMP with objectively measurable tasks (Faw 2009, 12). As part of this, a lot of research examined the functional equivalence between internal visual imagery and the actual perceptions these images were thought to simulate (Cooper 1995, 1576). As in the 1950s, these investigations took pains to distinguish mental imagery from the perceptual-misjudgements associated with

[123] As Peter Ashworth (2008, 9–10) notes, the shift towards cognitive psychology retained a methodological viewpoint framed by the same positivist commitments found in the behaviourist approaches that sought to discover the definite enduring characteristics of a unitary real world (of which the individual is a part).

hallucinations (e.g. Reed 1972, 45). Indeed, this distinction was even more important given that extreme vividness of everyday imagery was also being investigated as a risk-factor for hallucinations. For example, highly-vivid imagery was hypothesised to increase individual susceptibility to experiencing those pseudohallucinations induced by sensory deprivation, fatigue, direct cortical stimulation, and hallucinogenic drugs (Holt 1964, 257, 259).

During the latter part of the 1970s and 1980s, several specific imagery-focused research domains developed.[124] These domains fostered research into image generation and transformation; especially as these images related to language comprehension, concrete reasoning, abstract reasoning, perception, learning, memory, emotional processing, and motor control (S. M. Kosslyn, Behrmann, and Jeannerod 1995, 1136–43; Stephen M. Kosslyn, Ganis, and Thompson 2010, 3; Joel Pearson 2014, 178–79). Along the way, the concept of mental imagery became associated with the types of data that were imbedded within information processing systems (S. M. Kosslyn, Behrmann, and Jeannerod 1995, 1136–1337). This association helped to frame research questions about the structural properties of mental images (S. M. Kosslyn, Behrmann, and Jeannerod 1995, 1337).

However, a collection of interconnecting and long-running debates quickly developed over whether mental images have actual structural properties or not. Within this context, the question was not about the content of the conscious thought but about the format that described how thought content can be represented (Joel Pearson and Kosslyn 2015, 10089). These depictive/descriptive debates returned to the earlier question of whether sense-imagery contributes to abstract thought. However, rather than arguing for/against imageless-thought, this new challenge asked whether reported experiences of mental-imagery involve

[124] It was during this time that Alistair Hannay's (1971) philosophical defence of mental imagery also re-awakened debate over the ontological status of mental images (Audi 1978; Hannay 1973; Kleiman 1978; Lawrie 1970).

SLMP at all. In doing so, these debates incorporated associated disputes over the relationship between visual mental images and real percepts and whether visual mental images were forms of sensory 'pictorial' depiction or non-sensory 'propositional' representations (e.g., Amiri et al. 2002; J. R. Anderson 1978, 1979; Bartolomeo 2002; S. M. Kosslyn 1981; Stephen Michael Kosslyn 1994; Mellet et al. 1998; Pylyshyn 1981, 2003; Reisberg and Heuer 2005).[125]

In contrast to some of the early experimental studies into the individual variability of imagery in multiple modalities, this revival of imagery research narrowed the focus to visual SLMP. For example, one of the most prolific avenues of research has been investigations into the parallels between visual imagery and visual perception (Intons-Peterson 1992, 45). In addition, investigations of visual imagery contributed to a wide range of areas in cognitive psychology: including research on working memory, spatial knowledge, and the mental 'models' required for reasoning (Denis 2012). As a result, visual imagery is by far the most extensively studied modality – to the extent that the term mental imagery is often used as a synonym for visual imagery.[126] Given this, studies of visual imagery became the "paradigmatic 'example' of a more general ability to generate and process internal objects regardless of the sensory modality of the single image" (Belardinelli and Di Matteo 2002, 204). In this way, the question of whether mental imagery is actually 'depictive' rather than just 'descriptive' was eventually carried over into research that has explored sensory modalities other than visual imagery (Hubbard 2010, 322; Intons-Peterson 1992).

These debates over the existence and functional value of mental images re-opened unresolved disputes from the earlier imageless-thought. As in the earlier debates, proponents

[125] For an early overview see (Roeckelein 2004, 294–305). Also note that these debates also intersected with those in philosophy of mind (N. J. T. Thomas 2014b); for example, see M.R. Bennett and P.M.S. Hacker (2003, 186–98).

[126] For some examples of this, see: (Stephen M. Kosslyn, Ganis, and Thompson 2010, 3; M. Martin and Williams 1990, 268; MacKisack et al. 2016).

on both sides of the newer imagery-debates relied on their own introspective experiences to support their (contrasting) views of a single 'normal' form of thinking (either image-based or imageless/propositional depending on the introspective experiences of the proponent). For example, Zenon Pylyshyn's descriptivist arguments have been described (by prominent supporters of the alternative 'depiction' account) as echoing John B. Watson's 1913 denial of the existence of mental images (Stephen M. Kosslyn, Ganis, and Thompson 2010, 3). Likewise, the positions of investigator's on both sides have been criticised as being shaped by their own subjective experiences of mental imagery (Reisberg, Pearson, and Kosslyn 2003). Whatever their positions, both debates positioned experiences of perceiving, imaging, and (verbal or abstract) thinking as three mutually exclusive processes.[127]

Debates between antagonistic depiction/description positions were further complicated by attempts to reconcile experimental studies of mental imagery with the symbolic computationalism popular in the cognitive sciences (N. J. Thomas 2002).[128] Therefore, although there were other non-computational mechanisms proposed for imagery, the focus on the imagery-debate left little room for these to develop (N. J. Thomas 2002). Instead, these debates over the existence of quasi-perceptual visual images resulted in numerous experiments investigating the role of imagery in providing sensory-based mental representation (Denis 2012, 205). Indeed, these debates combined with advances in technological methods to facilitate a growing interest into the neural bases of mental imagery (Farah 1995, 1455).

In the last two decades of the twentieth-century the central questions narrowed: focusing on whether or not a distinct component of functional neurological architecture

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127 Note that there are exceptions where scholars question these underlying assumptions, for examples see: (de Haan and Aleman 2002; Grossberg 2002).

128 For an account of this debate in relation to intersection between philosophical and psychological views of imagery, see (Tye 2000).

produces the subjective experience of deliberately generating visual mental images (Farah 1995, 1455). Although the answers to this question remain elusive (and continue to be investigated), recent research has once again begun exploring the roles that mental imagery might play in a wide range of neurocognitive functions. For example, in the introduction to the recent *Frontiers Research Topic* on mental imagery, Joel Pearson and Stephen M Kosslyn (2013, 5) highlight the inclusion of a range of investigations: "from the role of imagery in music, biomechanics, and mathematics to the functions of the cerebral hemispheres in imagery and imagery's effect on sensory perception".

These newer approaches suggest an interest in mental imagery as a bi-directional link between perceptual experiences and the 'higher-functions' of memory, imagination, language comprehension, and abstract reasoning. This highlights a potential further adaptation of the mediator-view of SLMP. However, despite this and earlier modifications, the mediator-view of SLMP continues to carry entrenched associations that structure these investigations into the role of mental imagery in neurocognitive processes. Indeed, as will be detailed in later chapters, the expectation that mental imagery mediates between perception and higher-functions provides one of the tacit background assumptions which allows the concept to be used to investigate this range of neurocognitive functions.

In line with this, mental imagery is routinely characterised in terms that would explain the ordinariness of these SLMP within the knowledge context of the philosophical tradition within which the mediator-view of SLMP emerged. That is, although spontaneous/involuntary mental imagery are investigated, research has overwhelmingly focused on deliberately self-generated imagery (Brewin et al. 2010, 210). Indeed, while twelve of the sixteen experiments published by Betts (1909) investigated spontaneous imagery, it was his questionnaire for voluntary imagery that came to be adopted as prototype approach to investigating individual abilities in mental imagery.[129]

This focus on the role of deliberate imagery in cognitive processes such as memory and language can be understood in relation to the precarious position of mental imagery research as it re-emerged in the 1960s. That is, the difficulty of establishing mental imagery as a valid scientific interest required delineating the notion of 'mental imagery as cognitive function' from abnormal or undesirable SLMP such as hallucinations. As such, proponents of the value of mental imagery to neurocognition reinforced the view that functional mental imagery is characterised by volitional control, manipulability, and ability to be regulated by rational judgement. Furthermore, the boundaries of these delineations typically distanced the concept of mental imagery from those characteristics – such as, perceptual similarity, external location, and lack of volitional control – thought to hinder rational adult thought. In more recent contexts, the need to differentiate mental imagery from hallucinations is rarely encountered. Nonetheless, as detailed in Chapter Three, sense-images are still characterised in the same terms used to justify mental imagery as relevant to understanding the mediating role of SLMP between perception and higher-functions. Indeed, it is characterised in this way that mental imagery can operate as a stable concept for investigating ordinary SLMP.

4.3 Hallucination as Dysfunctional Neurocognition

There are differing accounts as to the development of the concept of hallucinations.[130] Of these, I draw predominantly on those that emphasise the dynamically contingent trajectory by which the concept of hallucinations came to be used as a symptom of mental illness; a

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129 Also see: (K. White, Sheehan, and Ashton 1977, 162). For examples of adaptations of Betts' questionnaire see (Sheehan 1967; K. D. White, Ashton, and Law 1978).

130 This historical sketch is intendend to complement that provided in the previous section. It is informed by historical accounts of hallucinations specifically (rather than broader contexts), with specific examples chosen to illustrate elements of interest within the intersection between the concepts of mental imagery and hallucinations. Also see see, pp. 12, 131 -132, 152, 322.

historiographical approach that allows room for the unresolved debates over the philosophical, social, and medical conceptualisations of SLMP (and their relevance to psychiatric practice).[131] This approach is appropriate given the elusiveness of achieving consensus on the precise definition of hallucinations (Larøi et al. 2012, 724; Mast 2005, 739). As outlined in Chapter Three, definitions and uses pivot around a central notion – SLMP experienced with a compelling sense of perception – yet supplement this with a range of typical characteristics that differentiate these pathological symptoms from benign SLMP. Therefore, in this section I will focus on highlighting some historical episodes that contributed to the current use of hallucinations (as a conceptualisation of SLMP that are experienced with a compelling sense of perception) to investigate dysfunctional neurocognition.

The term 'hallucination' has a longer history that is only tangentially related to the concept of hallucinations as it is currently used.[132] In addition, numerous other terms have been proposed for pathological experiences of SLMP that have a compelling sense of reality. This is especially evident in the eighteenth-century disease classificatory lists (Berrios and Marková 2012, 57).[133] However, it was only in the nineteenth century that the term 'hallucinations' was successfully united with the concept that some SLMP (those with a compelling sense of perception of any modality) can be symptomatic of the physical dysfunctions underlying multiple mental illnesses (André Aleman and Larøi 2008, 12; Berrios 1996, 35; Berrios and Dening 1996, 754). This process of unification is typically attributed to

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131 For example, the historiographical approaches favoured here are congruent with philosophical arguments against treating mental kinds as natural kinds (e.g., Haslam 2014; Schaffner and Tabb 2014; Zachar 2014); see Fiona Macpherson's (2013a) discussion of the recent diversification of philosophical conceptions of hallucinations and the neglected role of these in clinical and experimental considerations.

132 See Appendix 1 (Annotated Glossary) entry *hallucinations* for examples.

133 Examples include *deluded imagination* (Battie 1758, 5–6) and *sensitive insanity* (Arnold 1782, 158) – see Appendix 1 (Annotated Glossary).

the influential definition proposed by Jean-Étienne Esquirol (Berrios and Marková 2012, 59; Blom 2010, 219; de Boismont 1860, 26–27; Peyroux and Franck 2013, 7).

Esquirol (1845, 110) rejected earlier uses of the term for false perceptions or damage to the senses; proposing instead that to experience an hallucination is to "suppose the presence of an object proper to excite one of the senses, although these object may be beyond their reach".[134] In Esquirol's (1845, 109) account, hallucinations are cerebral phenomena that occur independently of the senses and arise from an over-excitation of the normal brain function underlying memory and imagination.[135] Esquirol's approach provided the ground work for the construction of a concept of hallucination as a stable 'natural kind' with all varieties of sense modalities sharing the same biological mechanism (Berrios and Marková 2015, 12).[136] Therefore, although not accepted wholesale, it set the stage for the debates over how to differentiate hallucinations (as a symptom of physical pathology) from ordinary experiences of SLMP.[137]

Esquirol's approach to hallucinations was taken up and developed by other psychiatrists within the 1840s continental discourse and, eventually, by English-speaking mental medicine practitioners (Blount 1856). As it was taken up, some aspects of Esquirol's approach were abandoned. For example, one of Esquirol's unrealised intentions was to escape the association between experiences of hallucinations and individual failings in reason (Rabkin

[134] Esquirol also distinguished hallucinations from false sensations, illusions of the senses, erroneous perceptions, errors of organic sensibility, somnambulism, dreams, and ecstasy (Esquirol 1845, 107–8).

[135] Also see: (Berrios 1996, 37; de Boismont 1860, 27; Peyroux and Franck 2013, 9).

[136] Also see: (André Aleman and Larøi 2008, 12; Berrios and Marková 2012, 60–63; T R Sarbin and Juhasz 1967, 349).

[137] Esquirol drew on range of existing work, such as that of Etienne Bonnet de. Condillac (Berrios 1996, 37). However, although not entirely new, the influence of this approach was strengthened by the inclusion of Esquirol's 1817 and 1838 publications in the *Dictionnaire des sciences médicales*, the associated debates, and the wide dissemination of his work, see (James 1995, 145–57).

1970, 115). This intention is evident in statements by Esquirol (1845, 110) that, although most commonly found in the 'feeble minded' and associated with a wide collection of diseases, even those with "depth or reason, and… vigour of thought, are not always free from this symptom". Furthermore, Esquirol (1845, 107) suggested that the "conviction of the hallucinated is so entire and sincere, that they reason, judge, and decide with reference to their hallucinations". This conviction was described as stemming from a habit of associating the pretend sensation with an external object; a habit that eventually "lends a reality to the production of the imagination or memory, and persuades the subject of hallucinations that what he actually experiences could [only occur with] the presence of external bodies" (Esquirol 1845, 107).

In this way, Esquirol positioned the pathology of hallucinations as developing when SLMP with a compelling sense of perception are experienced as so frequent, or persistent, that this over-excited memory or imagination is believed to be real. Yet, despite these efforts to allow the concurrence of hallucinations and reasoned thought, Esquirol actually strengthened the mediator-view that positions experiences of confusing SLMP for perception as a failure to regulate memory and imagination processes (Berrios 1996, 37; Peyroux and Franck 2013, 8). This can be seen in Esquirol's influential distinction between hallucinations and illusions: illusions were (and are) regarded as an error of the sensory system easily rectified by reason; hallucinations, in contrast, were (and are) positioned as a dysfunction of the brain that can confound reason (Berrios 1996, 38).[138] For example, as part of this distinction, Esquirol suggested that lack of insight regarding the unreality of a hallucinatory experience is due to the strong resemblance of the SLMP to ordinary perception (Berrios and Dening 1996, 754).

[138] The conceptual distinction between experiences redolent of Esquirol's definitions of illusions and hallucinations had been proposed since Antiquity (Mora 2008, 200).

Esquirol's attempt to explain the difference between ordinary SLMP and those experiences of SLMP that can be confused for perception was taken up and modified in a range of unexpected ways within the ensuring debates over the concept of hallucinations. For example, also highlighting the importance of regulating SLMP, J.H. Blount (1857, 516) described hallucinations as compatible with sanity as long as they are able to be corrected by higher faculties. Similarly, Jules Baillarger argued that it was the involuntary characterisation of hallucinations that provided the initial failure of the intellect; hallucinations occurring in the "opposite direction to normal sensations" (Berrios 1996, 39).[139]

However, diverging from Esquirol, Baillarger considered that the most frequent, complicated, and clinically interesting form of hallucinations take the form of voices from invisible interlocuter addressing the patient in the third-person (Berrios 1996, 37–39). Based on this view, Baillarger differentiated between sensory modalities: separating the (sometimes pathological) hallucinations of sight, touch, taste, and smell from the exclusively pathological auditory and verbal hallucinations (Lothane 1982, 336). A similar argument was also presented by G.F. Blandford (1874), who claimed that 'hearing' voices represents a specific and especially pathological form of hallucinations.

Brierre de Boismont (1860, 413) also suggested that the hallucinations found in sane people are most commonly those of sight, while "in the insane, those of hearing are the most frequent and most complex". However, Brierre de Boismont proposed two different sub-categories for hallucinations: unusually intense yet non-pathological images (voluntary experiences produced through faith, enthusiasm, or belief); and pathological experience of SLMP with a physical cause disrupting reason (André Aleman and Larøi 2008, 13; Peyroux and Franck 2013, 9). These attempts to categorise different forms of hallucinations

[139] For this phrase, Berrios draws on J. Baillarger 1846 Des Hallucinations. Mémoires se l'Académie Royale de Medicine Vol.12 pp273-475

contributed to debates over "whether hallucinations are a pathological and morbid symptom or only an exaggeration of a normal phenomenon" (Blandford 1874, 516). Following Esquirol, Baillarger and Brierre de Boismont had promoted conceptualisations of hallucinations with subcategories to incorporate nonpathological SLMP. In contrast, many others, including Louis-Françisque Lélut and François Leuret, advocated for a concept of hallucination that exclusively denotes a pathological phenomenon (André Aleman and Larøi 2008, 13; D. B. Smith 2007, 70–72).

These debates over conceptualisation of hallucinations (as exclusively pathological or not) provided the chief dispute at the 1855 and 1856 meetings of the Medico-Psychological Society of France (Blandford 1874, 516). These disputes centred on determining whether the key characteristics of pathological hallucinations were their abnormal occurrences of imagery (external location, high vividness) and/or poor self-regulation (lack of volitional control or reasoned judgement) (Berrios and Dening 1996, 755–56; André Aleman and Larøi 2008, 13). In relation to these debates, various additional terms were suggested to describe SLMP that differed from ordinary imagery yet did not share the full set of characteristics of those hallucinations associated with insanity (Berrios and Dening 1996, 756). For example, in the 1880s Victor Kandinsky described 'hallucination-like' experiences with the vividness and involuntary character of true hallucinations yet without a compelling belief in the external reality of the supposed perception (Berrios and Dening 1996, 758).[140] However, none of these gathered much support; lack of empirical techniques to test the various proposals leading these debates to end inconclusively (Berrios 1996, 40). As such, hallucinations continued to conceptualise both a special case of disease symptomology and the dysfunctional extreme of ordinary mental phenomena.

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[140] Another example is, Leon Marillier's (1862–1901) notion of 'veridical hallucinations' which also did not adhere to Esquirol's definition (see: Le Maléfan and Sommer 2015).

Throughout these debates, explanations for pathological hallucinations positioned the compelling sense of perception of these SLMP as resulting from dysfunctional imagery: whether due to an abnormal degree of perceptual similarity, a lack of control and/or a failure of judgement. This trajectory has been attributed to both the lack of consistency within various proposals for non-pathological hallucinations, and the focused arguments in favour of more narrow uses of the concept for pathological SLMP (André Aleman and Larøi 2008, 13; D. B. Smith 2007, 70–72). These debates fit neatly within the broader philosophical traditions within which a mediator-view of SLMP was well-established. This tradition assumes that there exists a common intuitive knowledge of what is real, and that an inability to maintain rational relations with the external world is due to an individual error in perception or judgement (Rabkin 1970, 119).

These debates remained unresolved. However, the persisting philosophical assumption posited that there exists a common intuitive knowledge of what is real. Despite this, interest in examining why SLMP might lead to errors in judgement about perception was gradually side-lined. Instead, any inability to maintain rational relations with this shared external world came to be explained primarily as an individual's failure to regulate their sensory experiences. This shift coincided with a focus on self-regulation within the development of the broader psychiatric discourse that provided the conditions for approaching pathological hallucinatory experiences as a scientific object (L. M. Blackman 1994; L. Blackman 1996).[141]

Using hallucinations as concept for a type of scientific object worthy of experimental investigation became more feasible once a neurological-based mechanism for hallucinations became accepted by most psychiatrists. This feat has been attributed to the theory developed

[141] More broadly, it has also been argued that this view is culturally specific, and that the "particular dimensions of the way mind is imagined in any society…shape the incidence and modality [of various forms of SLMP]" (Luhrmann 2011, 77).

by August Tamburini in the 1870s and 1880s (Berrios 1996, 41). Tamburini (1990, 156) described sensations perceived as real perceptions as occurring due to morbid, internal sensations being propagated to all parts of the sensory system. It was this propagating sensation that provided the 'fundamental mechanism for hallucinations' as the over-excitation of cortical sensory areas responsible for collecting and storing sensory impressions in the service of conscious perception (Tamburini 1990, 156). In this way, Tamburini's proposed mechanism built upon the conceptualisation of hallucinations as a dysfunction of the imaginative and memory processes that had formed under Esquirol's influence. In doing so, Tamburini brought psychiatric and neurological hallucinations together into the same model; legitimising a neurophysiological approach to psychiatric phenomena (Berrios 1996, 41). However, in contrast to Esquirol, Tamburini dismissed the relevance of patient histories of the subjectivity of their experience (Berrios 1996, 42).

This disinterest in subjective content can be understood within the context of the consolidation of psychiatry as a medical speciality during the nineteenth century. During this process of specialisation, the earlier school of thought that explored the subjectivity of mental processes lost ground to the increasing dominance of organists and clinical psychiatrists by the second half of the century (Kales, Kales, and Vela-Bueno 1990, 13–14). In line with changes within medical thought more generally, this shift sought to identify the discrete biological processes causing diseases in relation to an idealised concept of the individual's normal function (Murphy 2009, 115).

This approach was congruent with the mediator-view that positioned hallucinations as dysfunctional imagery. However, by the late nineteenth century this mediator-view had begun to be challenged. Rather than a dysfunction of imagery, hallucinations were explained by a range of normal brain functions that, if disrupted, could cause hallucinations. For example, Jules Séglas 1892 proposed that hallucinations result from a disruption in the perceptive centres of the brain (Peyroux and Franck 2013, 11). As part of this development of Tamburini's theory, Séglas suggested two types of pathological hallucinations, the first involving language production regions of the brain and the second being produced by activation in the linguistic auditory centre (Peyroux and Franck 2013, 12).

This focus on explaining hallucinations as a dysfunction of the production or comprehension of language reflects the close relationship between scientific interest in hallucinatory phenomena and the developing disease concept schizophrenia (Peyroux and Franck 2013, 12).[142] Specifically, that the reported experiences of perceiving external speech in the absence of the relevant auditory stimulus (AVH) came to be considered a central diagnostic criteria for schizophrenia (Peyroux and Franck 2013, 12–13; S. S. Shergill et al. 2000). This focus on AVHs built on earlier arguments that auditory-hallucinations had more clinical relevance than hallucinations in other modalities. Since then, a number of broader trends had developed, including the turn towards language as the basis of thought within the dominant philosophical traditions (N. J. Thomas 2006, 2) and the developing neurological-focused notions of personhood in legal and economic contexts (Bassiri 2015, 47–49, 56). Therefore, although the relevance of AVHs to schizophrenia was debated, interest in AVHs eventually overshadowed scientific interest into hallucinatory experiences in other modalities (Collerton, Dudley, and Mosimann 2012, 77).

It was within this context that echoes of earlier debates over the characteristics that distinguish pathological hallucinations from other SLMP re-emerged. These renewed attempts to identify the distinguishing characteristics of pathological hallucinations generated a new selection of concepts for all those experiences of SLMP that existed at an intermediate

[142] The concept of schizophrenia, and the position of hallucinations as a primary or secondary symptom of this disorder, has a convoluted history that is beyond the scope of this project, see (Andreasen 1994; Boyle 1990; Kales, Kales, and Vela-Bueno 1990).

point between ordinary imagery and pathological hallucination. These intermediate concepts included a range of conflicting notions for nonpathological hallucination-like SLMP (Berrios and Dening 1996). Of these, I will focus on two influential yet contradictory descriptions of *pseudohallucinations*: one by Kurt Goldstein and another by Karl Jaspers (André Aleman and Larøi 2008, 19).

Goldstein argued that true pathological hallucinations were those believed to be perceptions while pseudohallucinations were those hallucinations that the patient knows are not real (Walker 2013, 83–84). Goldstein's approach positioned pseudohallucinations as continuous with hallucinations; differing only by the level of insight. In contrast, Jaspers positioned pseudohallucinations as continuous with 'normal imagery' – differentiated by their external location (Walker 2013, 83–84). For example, Jaspers differentiated between 'normal images' (experienced as a poorly detailed or unclear image 'seen' with the inner eye and dependent on will), pseudohallucinations ('seen' with the inner eye yet vividly detailed and independent of will), and pathological 'true hallucinations' (a tangible and concrete presence of an object seen in objective (external) space regardless of their sensory clarity) (Walker 2013, 83–84).

In line with Jasper's approach, a number of studies into hallucinatory phenomena in the 1930s investigated whether individual preferences in imagery-modality related to a susceptibility to hallucinate (Andrè Aleman and Vercammen 2013, 114). Similarly, several studies used questionnaires, such as those developed by Betts (1909), to measure the level of mental imagery vividness in subject reporting hallucinations (Andrè Aleman and Vercammen 2013, 114). However these approaches faced the same difficulties associated with measuring mental imagery vividness more generally and their results were inconclusive (Andrè Aleman and Vercammen 2013, 114–15).

Eventually the debates over the question of nonpathological hallucinations quietened; with just the occasional attempt to reconcile the inconsistencies. One such attempt was Kräupl Taylor's (1966) proposal for two distinct forms of pseudohallucinations: one a form of hallucination with insight and the other a vivid form of internal imagery (Berrios 1996, 51). Meanwhile, G. Sedmann (1966) provided a review of potentially similar phenomena described in the historical literature: including 'pseudohallucinations', 'psychic hallucinations', 'false hallucinations', and 'perceptive hallucinations'. Following this, Sedmann (1966, 45) attempted to clarify the characteristics of pseudohallucinations from those of imagery and hallucinations respectively. This distinction positioned imagery as internal and less 'concrete' than perception; pseudohallucinations as sensory-experiences yet recognised as distinct from perception; and true hallucinations as sensory-experiences with the conviction of perception (Sedmann 1966, 45). However, none of the various notions of pseudohallucinations developed into stable concepts: each merely provide a flexible category for SLMP that were reported with some or all the characteristics of typical hallucinations despite not being confused with perception (André Aleman and Larøi 2008, 19; Berrios and Dening 1996, 753).

Although losing currency, the term pseudohallucination still provides a flexible category for those 'imaginal experiences' that have an unclear relation to 'proper' hallucinations (Berrios and Dening 1996, 753). As such, these debates over pseudohallucinations can be understood as continuing the difficulties identified during the 1855-56 debates within the Medico-Psychological Society of France. In both cases, the questions centred on determining the pivotal characteristics (location, vividness, volitional control, or insight) required for distinguishing pathological hallucinations from experiences of SLMP that are either ordinary (imagery) or abnormal yet benign (nonpathological hallucinations). However, despite these debates remaining unresolved, hallucinatory experiences were increasingly reduced to neurological dysfunction during the twentieth century (e.g., Parish 1902, 335; Weiss and Heckers 1999).

Continuing the increasing focus on medical models of hallucination begun in the nineteenth century, twentieth-century psychiatrists zealously excluded social considerations from accounts of psychiatric disorders, such as schizophrenia, through fear of falling short of the standards of somatic medicine (T R Sarbin and Juhasz 1967, 349; Schaffner and Tabb 2014, 302). As such, in contrast to earlier interest in the meaningful content of hallucinations, theorising about their psychological mechanisms became associated with amateurs and nonmedical academics (Berrios and Marková 2012, 60). Focusing on the neuroanatomical processes underlying the dysfunctional self-regulation of a range of normal functions – rather than just imagery – the question of distinguishing hallucinations from imagery was able to be discarded unresolved. Instead, the 'essence' of the concept hallucinations stabilised such that, by the end of the twentieth century, it was able to be used without explicit definitions or a clear point of delineation from other forms of SLMP (other than obliquely justified references to typical characteristics). Indeed, as detailed in Chapter Three, hallucinations continue to be routinely used as an independent concept for investigating those undesirable experiences of abnormal phenomena considered indicative of mental illness and presumed to result from a yet to be unidentified neurocognitive dysfunction.

4.4 An Historical Interdependence between Mental Imagery and Hallucinations

The historical context above provides a time-lapse type view of how the concepts of mental imagery and hallucinations developed in relation to each other. I began by exploring how reoccurring philosophical interest in the role of SLMP in thought led to the 'classic' mediator-view of SLMP of the nineteenth century. According to this view, ordinary SLMP mediate between perception and abstract thought, and abnormal SLMP are due to physical or mental dysfunction that disrupts the judgement processes that regulate ordinary SLMP. As detailed earlier, the series of associations inherent in this view position ordinary SLMP as able to safely mediate between perception and thought as long as active and voluntary or, if passive, as able to be controlled by rational judgement. By extension, a lack of control and/or a failure to correctly judge ordinary SLMP disrupts reason and can lead unregulated SLMP to be confused for perception.

During the nineteenth and twentieth centuries there were several explicit attempts to distinguish between SLMP conceptualised as either mental imagery or hallucinations. These attempts drew on mediator-view associations about SLMP to propose characteristics that indirectly explain why some experiences of SLMP can be appropriately regulated by reasoned judgement while others cannot (as summarised in Table 5).

Table 5: Characterising concepts in the context of mediator-views of SLMP

	Mental Imagery	Hallucinations	Role of Characteristics in Mediator-view of SLMP
Perceptual Similarity	Low similarity to perception	High similarity to perception	**Explains why SLMP are (or are not) able to be regulated by reasoned judgement**
Reported Location	Internally located	Externally located	
Volition and Control	Voluntary and/or Controlled	Involuntary and Uncontrolled	
Attribution of Source	Self-attribution	Other-attribution	**Measures the degree that SLMP are regulated by reasoned judgement**
Level of Insight	Insight maintained	Lack of insight	

In short, characteristics thought to explain why some SLMP are easily distinguishable from perceptual reality were associated with mental imagery. In contrast, characteristics thought to explain why some SLMP have a compelling sense of perceptual reality became associated with hallucinations.

Drawing on the theoretical approach developed in Chapter Two, the characterisation of each concept can be understood to have developed within the context of an available body of knowledge to individuate instances of SLMP. Individuated within this body of knowledge, the inferential role of each concept operated to provide an explanatory link between the term and the type of SLMP to be investigated further: ordinary or abnormal experiences of SLMP. Recalling the present uses of the concepts of mental imagery and hallucinations (detailed in Chapter Three), the inversely related typical characteristics of each can therefore be understood as individuating each from other concepts of SLMP (including each other) within the knowledge-context provided by mediator-views of SLMP.

However, while the inheritance of these mediator-view associations remains evident in the current concepts of mental imagery and hallucinations, this does not explain why these two concepts came to be used independently of each other. Answering this question requires recalling that the classic mediator-view of SLMP was abandoned within the twentieth-century uses of the concepts of mental imagery and hallucinations. This abandonment of their shared philosophical foundation can be seen in the distancing of each concept from the basic premise of the mediator-view during the early twentieth century. For example, in the case of mental imagery, the debates over the value (and very existence) of images relegated SLMP to inconsequential curiosities of childhood thought.

Meanwhile, hallucinations came to be attributed to a range of dysfunctional processes of which mental imagery was only one. Along the way, a range of intermediate concepts were proposed to account for all those SLMP that failed to conform to typical characterisations of either mental imagery or hallucinations. Each of these proposals offered different combinations of characteristics to explain how the SLMP in question differed from mental imagery and/or hallucinations. In doing so, overlapping combinations of characteristics were used: to distinguish between mental imagery and dysfunctional forms of SLMP on the one hand; and to distinguish between hallucinations and various forms of non-pathological SLMP on the other (see Table 6).

Table 6: Additional conceptualisations of SLMP during the early twentieth century

	Typical Mental Imagery	Eidetic Imagery	Pseudo-hallucinations (Jaspers)	Pseudo-hallucinations (Goldstein)	Typical Hallucinations
Perceptual Similarity	Low	High	High	High	High
Location	Internal	External	Internal	External	External
Volition	Voluntary	Voluntary	Involuntary	Involuntary	Involuntary
Control	Manipulable	Manipulable	Uncontrolled	Uncontrolled	Uncontrolled
Duration	Fleeting	Persistent	Persistent	Persistent	Persistent
Attribution	Self	Self	Variable	Others	Others
Insight	Maintained	Maintained	Lacking	Maintained	Lacking
Subjective experience	Positive	Positive	Variable	Variable	Negative
Impact	Benign	Benign	Benign	Benign	Disruptive
Content	Useful	Useful	not specified	not specified	Unwanted
Frequency	Variable	Frequent	Variable	Variable	Frequent

These intermediate types of SLMP highlight the ambiguous uses of the concepts of mental imagery (as ordinary) and hallucinations (as pathological). Within this ambiguity, these intermediate categories provided a parley space. It is within this parley space that inverse sets of characteristics were able to be used in different combinations: firstly, to negotiate the point of delineation between the concepts of mental imagery and hallucinations; and, secondly, to negotiate how to distinguish between functional and dysfunctional SLMP in relation to the independent use of each of these concepts.

This reliance on inverse sets of characteristics to differentiate between various forms of SLMP side-stepped each other by each drawing on different associations inherited from the nominally discarded mediating-role view of SLMP. In doing so, the intermediate types of SLMP obscured the interdependence between the characterisation of mental imagery-as-function and hallucinations-as-dysfunction. Increasingly, mental images and hallucinations were treated as independent concepts: mental imagery merely one of the many common elements that contribute to a range of neurocognitive functions; and hallucinations as due to the dysfunction of ordinary neurocognitive functions, of which imagery became merely one unlikely candidate.

This suggests, somewhat counterintuitively, that the inverse characteristics that developed to delineate between the concepts of mental imagery and hallucinations stabilised because of an inability to resolve the distinction between those characteristics of SLMP reported as contributing to either functional or dysfunctional behaviour. This relationship between the concepts of mental imagery and hallucinations as each is used to investigate different forms of SLMP can be articulated by drawing on the literature outlined in Chapter Two. In this light, the characterisations of the concepts of mental imagery and hallucinations can be understood as having a key role in individuating instances of functional and dysfunctional forms of SLMP for investigating the underlying explanatory mechanisms for ordinary and undesirable experiences of SLMP respectively. Furthermore, the concepts of mental imagery and hallucinations can be considered to have overlapping inferential components that embody the relationship between their diverging epistemic goals.

I will return to these considerations in Chapter Eight. For now, the inverse characterisations of ordinary and undesirable forms of SLMP can be understood as having helped to individuate functional and dysfunctional forms of SLMP in ways that structured the uses of the concepts of mental imagery and hallucinations as independent tools in neuroimaging experiments. Firstly, although used as discrete concepts, the inverse characterisations of mental imagery and hallucinations draw on entrenched associations inherited from the nominally rejected mediator-view of SLMP dominant during the early nineteenth century. Secondly, by supporting the uses of these concepts to explain functional and dysfunctional forms of SLMP, mediating-role associations about SLMP provide the structure within which the concepts of mental imagery and hallucinations can be simultaneously delineated in relation to each other and used independently of each other.

Therefore, to conclude, the intersecting historical episodes that have contributed to the development of mental imagery and hallucinations as independent concepts help to reveal a series of shared associations inherited from a mediator-view of SLMP. Considered in relation to the approach to conceptual practices developed in Chapter Two, these shared associations can be understood as providing an unarticulated structure within which the interdependent concepts of mental imagery and hallucinations each came to be used, independently of the other, for investigating discrete epistemic goals within neuroimaging experiments. In this way, the historical interdependence of the inverse characterisations of the concepts of mental imagery and hallucinations continues to be relevant to the current uses of these concepts as independent tools for investigating the role of SLMP-neuroanatomical-correlates and for explaining either the functional experiences of mental imagery or the dysfunctional experiences of hallucinations. I will explore this relevance further in the following chapters.

5 Collecting and Analysing Documented Neuroimaging Experiments

In neuroimaging experiments, the anatomy and physiology of the brain can be studied to investigate the relationship between mental processes and neurocognition (D'Esposito, Kayser, and Chen 2009; Habecker, Daniels, and Renshaw 2009). There are well-known challenges to any knowledge generated by these neuroimaging experiments. Many of these challenges reflect aspects of experimental practice that extend beyond context of neuroimaging. For example, false-positive errors are common to the practice of null-hypothesis significance testing during the study of group differences (Fine and Fidler 2015, 1452; Fidler and Loftus 2009). In addition to these wider concerns, there are long-running debates over the best technical strategies for mapping cognitive function(s) to neuroanatomy (J. B. McCaffrey 2015; Poldrack and Yarkoni 2016). Many of the challenges underlying these debates predate neuroimaging techniques (Borck 2004, 2008, 2016). In addition, there are a wide range problems with standard techniques in neuroimaging experiments specifically – many of which are being met with promising proposals for change (e.g., Poldrack 2012; Poldrack and Yarkoni 2016; Thirion et al. 2007).

In addition to these technical difficulties, there are also conceptual challenges that go largely unacknowledged within the neuroimaging community (Poldrack and Yarkoni 2016).[143] One of these challenges is the use of conceptual taxonomies that rely on behavioural observations that have yet to be updated in light of neuroscientific knowledge (Bunzl, Hanson, and Poldrack 2010, 54; Lenartowicz et al. 2010, 690). These outdated conceptual taxonomies carry tacit associations that are not being explicated as formal inferences about

[143] These issues draw attention to value of examining neuroimaging experimental practices that extend beyond my focus on conceptual tools. For example, the use of fMRI techniques could be examined in terms of the human-nonhuman dynamics highlighted within the strand of STS discussed in Chapter One. Another avenue for examining the use of fMRI techniques is provide by the notion of materially-mediated *observation* practices explored by resent work within STS and HPS (e.g., Nasim 2013; Vertesi 2014).

the neuroimaging data (Poldrack and Yarkoni 2016, 591). It is in this context that Russell Poldrack and Tal Yarkoni (2016, 591) argue that different causal explanations are being proposed for similar observable experimental outcomes depending on the context.

The notion of tacit assumptions in Poldrack and Yarkoni's argument is congruent with my own theoretical approach to analysing the use of scientific concepts in experimental practice (detailed in Chapter Two). In addition, Poldrack and Yarkoni's assessment is supported by the argument I presented in Chapter Four. To restate it briefly, I argued that the concepts of mental imagery and hallucinations share a set of associations that provide an unarticulated structure within which each came to be used, independently of the other, for investigating different goals within neuroimaging experiments. In relation to this, using mental imagery and hallucinations as independent tools for pursing discrete goals can be understood as simultaneously reflecting and obscuring their entrenched associations inherited from their historical interdependence (Œ. T. Smith 2018).

These arguments raise additional questions. In this chapter, I focus on outlining a method for examining whether these entrenched associations continue to structure the uses of these two concepts in neuroimaging experiments. To start, I will detail the three step multi-method approach I developed for collecting and analysing published neuroimaging experiments. Following these details, I will discuss some preliminary considerations that arose when following these methodological processes. These considerations will be presented as four contextual discussions – each providing part of the groundwork for a more focused analysis of the articles collected (to be detailed in Chapters Six and Seven).

The first of part of this context requires introducing the main material-technique shared by all the documented experiments I will analyse. The second demonstrates that the material instruments in these neuroimaging experiments are comparable; similar enough that the point of distinction between the articles compared are the different concepts used to investigate SLMP. In the third discussion, I focus on some of the challenges I encountered in developing a comparative analysis of the uses of the concepts of mental imagery and hallucinations in these neuroimaging experiments. Finally, in the fourth discussion I demonstrate how the comparative analysis to be presented in later chapters also supports the arguments that I presented in Chapters Three and Four: that the independent uses of the concepts of mental imagery and hallucinations are each structured by their interdependent histories. Having reiterated this argument, it will then be possible to turn to the question of interest. To this end, Chapters Six and Seven will present the comparative analysis I undertook following the method outlined in this chapter.

5.1 A Mixed Method Analysis of Published Experimental Practices

The method detailed below includes a series of primarily qualitative analyses of a systematically selected collection of documented neuroimaging experiments. Within this context, qualitative methods (typically involving the analysis of categories of non-numerical data such as words and images) are contrasted with quantitative methods (that involves analysing data that can be handled numerically). While this distinction between qualitative and quantifiable variables can become ambiguous in practice, it is an influential way of differentiating between types of data (Schwandt 2001, 213–15; Vogt and Johnson 2016, 354–56). In addition to this distinction, research described as qualitative typically draws on phenomenological traditions that emphasise descriptive accounts of subjective experiences and traditions adapting hermeneutic approaches to interpreting texts.[144] In line with these traditions, qualitative studies of science have employed methods ranging from ethnographic

[144] Given these traditions, qualitative studies are often considered to rely upon a relativistic epistemology. However, qualitative methods can be, and are, used within a range of theoretical frameworks: from strong social construction to positivist style realism, as well as – more recently – various approaches that seek to side-step this dichotomy (Forrester 2010, 18–32).

approaches (e.g., MacLeod and Nersessian 2013; Thorén 2015) to interpretative analyses of existing scientific texts (e.g., Michel Callon, Law, and Rip 1986b, 1986; Goddiksen 2015).

Within the diverse approaches to qualitative research, the value of existing written documents as sources for qualitative analysis is often down-played (Finnegan 2006). Indeed, 'qualitative data' is sometimes narrowly defined as previously undocumented data and primary sources collected by researcher through observations, interviews, archival work, and related practices (e.g., Vogt and Johnson 2016, 354). Even when existing written documents are included as sources of data for qualitative research, they are typically treated as secondary to other data sources and largely limited to grey literature, personal documents, and non-technical texts (e.g., Finnegan 2006; Glenn A. Bowen 2009; Jupp 2006).

This association between qualitative analysis and the need to collect previously undocumented data can be understood, at least in part, in relation to the development of qualitative analyses as a distinctive approach within the social sciences. Here the specific value of collecting verbal qualitative data in the social sciences was contrasted to the analysis of data within existing documents common across many disciplines (Finnegan 2006, 138). Whatever the reasons, devaluing of published articles as a data source for social science research is now reflected in the types of qualitative methods that other disciplines adopt from the social sciences. For example, recent interest in qualitative methods within the Philosophy of Science have predominately adopted approaches based on "observational, interview and ethnographic investigations of science in real world contexts of practice" (Osbeck and Nersessian 2015, 18).

When compared to these records of real-world interactions, there has been little interest in analysing existing documentary sources of scientific practice such as published research articles. In studies that do offer qualitative analysis of published scientific documents the focus in on examining the dissemination of knowledge. For example, qualitative studies of published research articles have often focused on the rhetorical strategies used in disseminating scientific knowledge (e.g., Hyland 1996; Law and Williams 1982; Star 1983). More recently, qualitative studies of science focus on examining existing scientific texts as situated within broader contexts; including examining biotechnology patents (Bostanci and Calvert 2008); science education (Goddiksen 2015); and the difficulties of interdisciplinary research (Brister 2016).

However, in addition to presenting research findings for dissemination, peer-reviewed research articles also provide information about generating knowledge within experimental practices. Most obviously, published texts marshal experimental findings to argue for the validity of first-order knowledge claims (Thompson 1993). These first-order knowledge claims can be understood as providing "unit contributions…of scientific development" that – if incorporated into the structure of the relevant scientific discipline – can become accepted as scientific facts (Leydesdorff 1991, 75). In this way, research articles link together all those heterogeneous contributions to an experiment that can best support a 'synchronic translation' of the dynamics of practice (Law 1986, 49). Viewed in this way, published research articles offer inscriptions of scientific practice that can be treated as records of those experimental practices that generated the unit contributions to scientific knowledge that such texts aim to disseminate as first-order knowledge claims.

This is not to say that scientific practice can be reduced to texts, nor even that published records detail actual dynamics of experimental practice. Indeed, the report of an experiment only ever communicate a small portion of the knowledge and experience that provide the foundation within which researchers make justified assumptions about what to investigate and how (Fleck 1979, 96).[145] Furthermore, published research articles are tailored accounts

[145] Also see related points made by Hans Radder (1997, 654) and Rheinberger (2010a, 244–53).

of one or more experiments; accounts intended to present experimental findings in ways that best contribute to a specific field of scientific knowledge (Schickore 2011, 471). As such, focusing on the published accounts of experimental practice can obscure numerous elements of the dynamic generation and dissemination of first-order knowledge claims more broadly. Many of these broader elements have been explored by sociological studies into the convoluted processes by which experimental knowledge-claims become accepted as scientific facts (e.g., Latour and Woolgar 1987; Law and Williams 1982; Star 1983; Thompson 1993). In addition, a range of historical and philosophical studies of science have investigated the complex dynamics within experiments, as well as their role within broader scientific practices (e.g., Arabatzis and Nersessian 2015; Hacking 1998b; Rheinberger 2010a; Rouse 2011a; Shapin and Schaffer 2011).

These broader dynamics are important, and undoubtedly require further study. However, there is also value in examining individual experimental practices. As I am not currently interested in what becomes accepted as scientific facts, I instead seek to examine the uses of concepts in those experimental practices that are reported as having generated certain first-order knowledge claims (which I will refer to simply as 'knowledge-claims' from now on). Of course, much of the detailed practices that generate these knowledge-claims are not documented. However, those practices that are documented provide an account of the experimental procedures to which the generation of knowledge-claims are attributed. Specifically, published research articles can be understood as providing accounts of various aspects of experimental practice – including the experimental aims, designs, methodological procedures, empirical findings, and disciplinary contexts – that helped to *generate* the unit contributions to scientific knowledge proposed for dissemination in each publication. As such, it is these published accounts that help to translate experimental findings into knowledge that, if accepted, can then be applied in other practices.[146]

By approaching research articles in this way, peer-reviewed texts can be considered a form of scientific inscription that offers a valuable source of data for studying what is created and transformed within scientific experiments (Michel Callon, Law, and Rip 1986a, 11). In line with this view, I developed the following method to analyse the experimental practices reported to have generated knowledge-claims based on documented experiments that identified SLMP-neuroanatomical-correlates: a correlation between localised neural activity (as measured by neuroimaging techniques) and experiences of SLMP (conceptualised as either mental imagery or hallucinations).[147]

5.1.1 Step One: Collecting Comparable Article Sets as for a Systematic Review

To collect a representative sample of the published articles that reported on neuroimaging experiments investigating the underlying mechanisms for either mental imagery or hallucination, I developed a systematic process for collecting and sampling the available literature. Given that the articles in question document experimental results, the approach taken to this methodological step was to adapt the four-phases recommended in the *Preferred Reporting Items for Systematic reviews and Meta-Analyses* (PRISMA) statement for managing the flow of information during a systematic review (Moher et al. 2009, 267–68).[148] In these recommendations, the 'identification' phase focuses on identifying the literature relevant to

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[146] My approach here parallels those that study the published accounts of other types of knowledge-making practices. For example, Andrew Mendelsohn's (2017, 86–88) study of the use of published medical cases highlights the value of examining scientific knowledge as it is generated through the process of forgetting in a structured manner.

[147] This approach is limited to analysing scientific practices as they are *reported;* I will not speculate about the dynamics of the documented experiments obscured by these reports.

[148] There is also a complicated history on how standardised criteria for synthesising empirical knowledge were formalised that provides important context for how and why systematic reviews and meta-analysis are valuaed (Bohlin 2012).

the research question. The 'screening' phase culls the identified articles to remove duplicates. The 'eligibility' phase further limits the inclusion of studies based on consistent criteria. The 'include' phase begins with identifying those articles to include in a qualitative synthesis and ends with identifying those articles to be included in the quantitative synthesis of a meta-analysis if required. These phases help to ensure that reproducible steps are transparently reported when collecting and analysing literature relevant to a given research question (Liberati et al. 2009, 2).

Although a guideline for synthesising the results of randomised clinical trials, PRISMA also provides a basis for systematic reviews of other types of research, such as experiments assessing a given medical-intervention (Moher et al. 2009, 265). In addition, by encouraging explicit and transparent steps for selecting published research articles, these guidelines are valuable for structuring the process of collecting a representative sample of published research on a given topic. With this in mind, the four-phases in the PRISMA statement were adapted for multiple search streams and used to record the inclusion/exclusion criteria during the collection of research articles relevant to the research question (summarised in Table 7).[149] To this end, keyword combinations were used for a series of searches within OVID® databases.[150] This series of searches identified 884 scientific research articles published between 2004 and 2014 that documented neuroimaging experiments on human subjects that used the concept of either mental imagery or hallucinations.

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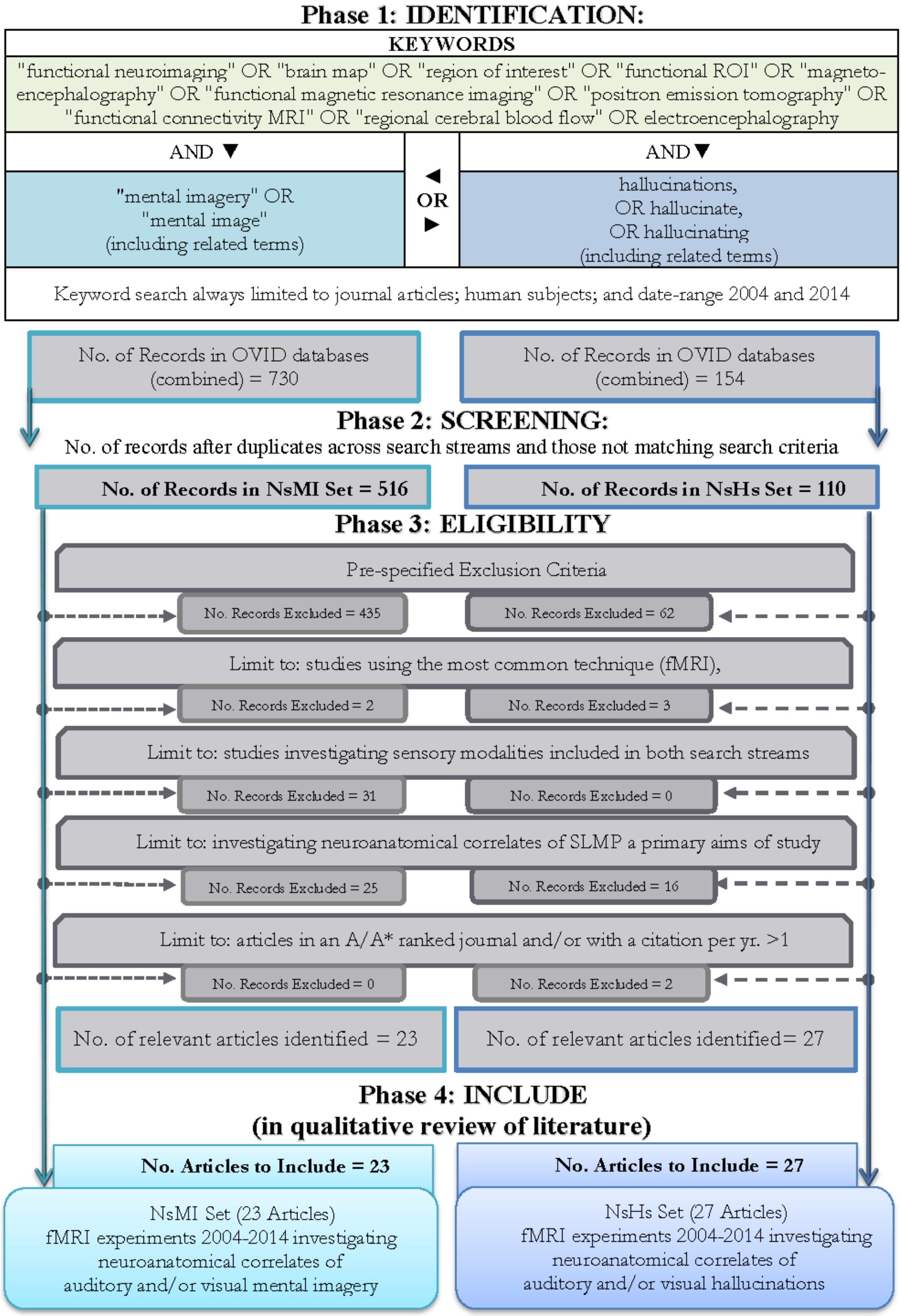
[149] See Supplementary Tables, Set 1 for more detail. Note that while details of the PRISMA checklist have been updated since I sampled the literature in 2014 the flow-chart I adopted remains consistent to both versions (Moher et al. 2015).

[150] Chosen due to the range of disciplines that undertake neuroimaging experiments, the OVID® databases allow specific searches in PsycINFO (the largest bibliographic database devoted to peer-reviewed literature in the behavioural sciences and mental health) and MEDLINE (the U.S. National Library of Medicine's premier bibliographic database, covering biomedicine and life science), as well as an 'All Journals' database search option.

Table 7: Managing the flow of information during a systematic review.

Source: adapted from the PRISMA statement's 'Flow of Information through the separate phases of a systematic review' (Moher et al. 2009, 4))



After an initial screening process, limiting the search results by removing duplicates, the remaining articles provided two sets of documents: neuroimaging studies using the concept of mental imagery (the initial *Set-M*, n = 516) and neuroimaging studies using the concept of hallucinations (the initial *Set-H*, n = 110*)*. Once these articles were collected, I applied a series of pre-specified exclusion criteria based on the research question to cull from both sets. This process removed all meta-analyses and literature reviews; articles written in languages other than English; articles investigating exogenous SLMP; and articles that did not include either mental imagery or hallucinations (or related terms) in the article's keyword list or abstract.

This process captured studies documenting a wide-range of neuroimaging techniques for investigating experiences of SLMP in any sensory modality. The outcome was still too broad, so several additional eligibility criteria were selected based. Firstly, as the overwhelming majority of articles in the initial search reported the use of fMRI techniques, the following round of the eligibility assessment reflected this. I therefore removed any articles that did not directly report on the use of fMRI techniques to investigate localised brain activity that correlated to experiences of either mental imagery or hallucinations (i.e., the SLMP-neuroanatomical-correlates). Secondly, the SLMP of interest were limited to those experienced in the visual or auditory modalities.[151] This choice was made to improve cross-set comparability (as the initial *Set-H* did not include studies on modalities other than visual or auditory hallucinations).

[151] Within this context, auditory-verbal SLMP (the experience of 'hearing' – to varying degrees of perceptual similarity – the voice of another person) are being classified within the broader auditory modality. It is also worth noting that I am using auditory-verbal SLMP as distinct from the broader category of 'inner speech' which is often used without distinguishing between non-sensory (condensed) "thinking in pure meaning" and sensory-like (expanded inner speech) experiences that appear "phenomenally as an exchange between voices in the head that bear many of the acoustic and functional properties of external speech" (Fernyhough and McCarthy-Jones 2013, 90).

The initial search also unintentionally captured several research articles that used the concepts of mental imagery and hallucinations to aid in the interpretation of the results of fMRI experiments even when only indirectly related to the aims of the experiment itself. While analysing these uses would be of interest more broadly, they are only of passing relevance to the research questions of this project. Therefore, additional rounds of the eligibility assessment excluded articles where the aim of the investigation did not require identifying SLMP-neuroanatomical-correlates. A final criterion was also included as a proxy for ensuring that the articles in each set were considered respectable scientific publications. This proxy was to include only those articles cited at a rate of once per year or more (as recorded by Web of Science at 20th April 2015) and/or published in a journal listed with an A/A* ranking from the *Excellence in Research for Australia (ERA) 2010 National Report* ('The Excellence in Research for Australia (ERA) 2010 National Report' 2011).[152]

As detailed, my method involved starting with a wide search and reducing this to manageable numbers by systematically excluding articles based on consistent criteria (adapted from the PRISMA guidelines for systematic literature reviews). In doing so, I collected fifty peer-reviewed articles documenting one or more fMRI experimental investigations of the localised changes in brain activity as these correlated with experiences of auditory and/or visual SLMP (see Table 7). Of these fifty articles, the experiences of SLMP investigated where conceptualised as mental imagery in twenty-three articles (the final *Set-M*) and as hallucinations in twenty-seven (the final *Set-H*).

[152] The ERA 2010 was used for national research funding in 2014 (when I began this research) and, while contentious and since abandoned, was considered broadly consistent with research evaluation frameworks in other countries at that time.

5.1.2 Step Two: Identifying Paradigmatic Examples of Documented Experiments

Each of these fifty articles reported knowledge-claims by drawing on the fMRI experiments that identified correlations between localised brain activity and experiences of SLMP (conceptualised as either mental imagery or hallucinations). My next step involved identifying those unit contributions to scientific knowledge supported by reported SLMP-neuroanatomical-correlates. To this end, I adopted textual-analysis techniques to examine the content of each individual document in turn. In this context, textual-analysis is a broad term for a range of systematic approaches to analysing text. What these approaches share is that each is governed by consistently applied rules for 'coding' passages of text by indexing them in a way that allows robust analyses of the selected text (Popping 2000 p.8). For this project, this involved a system of iterative coding consistently applied to each of the articles in Set-M and Set-H – copies of which had been uploaded into a computer-aided textual-analysis program (*Dedoose* (version 6.2.17) 2015). Then, drawing on the coding system outlined by Johnny Saldańa (2009, 45–146), I combined provisional coding for predefined grammatical and elemental codes with an exploratory stage of indexing additional content of relevance to the research questions. In this way, the provisional codes that I based on the research question were gradually refined using those terms and phrases identified during the exploratory coding of each individual document. This type of textual-analysis provides "a research technique for making replicable and valid inferences from [a set of] text to their content" (Popping 2000, p.7).

In the first round of this textual-analysis process I focused on indexing the range of terms for those neuroanatomical regions where changes in brain activity were investigated in relation to experiences of SLMP (i.e., the potential SLMP-neuroanatomical-correlates). In neuroimaging experiments these regions are typically identified by predefined anatomical landmarks, functionally identified region of interest (ROI), or by combining functional and anatomical criteria (Poldrack 2007, 68). However, in addition to these specific approaches, neuroanatomical regions based on gross anatomical formations are also used to communicate findings about neural activity in fMRI studies (Nolte and Angevine 2013, 841–53). [153] Given this, identifying the anatomical landmarks of the brain regions being investigated in an experiment required indexing a range of terms that identified overlapping neuroanatomical regions. This coding system reflects the range of anatomical terms used to identify the same brain region, as well the range of cognitive functions related to these anatomical features (Ashby 2011; Beaulieu 2001; Mazziotta et al. 2009; Poldrack 2006, 2007). Given this variability, the specific terminology used for brain regions within each article were checked against a selection of textbooks (Duvernoy 1991; Greenstein, Greenstein, and Greenstein 2000; Nolte and Angevine 2013; C. Watson, Kirkcaldie, and Paxinos 2014) and interactive neuroanatomical databases (Bernal and Perdomo 2008; Bowden 2015; Clarkson, Rosse, and Mejino 2015).

Once the various neuroanatomical terms were coded, each term was cross-referenced with a thesaurus of neuroanatomical 'synonyms, similar sounding non-synonyms, and terms of variable meaning' (Anthoney 1994) to enable cross-disciplinary comparisons. The various terms were then reconciled in relation to internationally recognised neuroanatomical terms as listed in University of Washington's Functional Model of Anatomy (FMA) database (Clarkson, Rosse, and Mejino 2015). The FMA specifically incorporates multiple approaches to aid in reconciling the different disciplinary definitions for neuroanatomical entities (Mejino et al. 2007). This cross-disciplinary relevance is provided by incorporating Brodmann area (BA) maps, the internationally accepted terminology for macro human neuroanatomy – as

[153] These macrostructures are considered to be more or less consistent across individual brains, however individual variability can still be found (Duvernoy 1991, 10; Nolte and Angevine 2013, 240).

adopted in the *Terminologia Anatomica* (2011) – and the more than 6500 neuroanatomical terms (of which about 4000 are synonyms) listed in the *NeuroNames* database (R. F. Martin et al. 2003; Turner et al. 2010).[154]

Once terminological variations were reconciled, it was possible to streamline the coding system in *Dedoose* for the most common brain regions. To do this, relevant 'child' codes were collected under a set of 'parent codes' based on internationally recognised neuroanatomical terms. Then, by applying the 'retroactive up-coding' function, those brain regions that were most commonly investigated in relation to experiences of both mental imagery and hallucinations were identified.

As part of this textual-analysis I incorporated 'summative content-analysis': an approach for identifying and quantifying latent content in text in order to qualitatively explore the usage of these content elements within a given context (Hsieh and Shannon 2005, 1283–86). This approach begins with a search for the appearance of particular content within the text, yet goes beyond a quantitative manifest-content calculation by interpreting the underlying meaning of these appearances within a given context (Hsieh and Shannon 2005, 1283–85). For example, not only did I analyse the appearance of various neuroanatomical terms in each of these articles, I also identified synonymous terms and implicit references to equivalent neuroanatomical regions. In addition, I drew on sources external to the data examined to validate this interpretation of the meaning of neuroanatomical content in these articles.[155]

From this first round of coding I identified twenty different brain regions that were of interest to neuroimaging researchers regardless of whether the SLMP being investigated were

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[154] Note that the NeuroNames database is continually developing; also, note that it bases the location of the Brodmann areas on K Brodmann's 1909 Beschreibung der einzelnen Hirnkarten (Leipzig: Verlag von Johann Ambrosias Barth).

[155] I would like to thank Dr Charles Malpas and Dr Bonnie Alexander for their comments on drafts of this chapter. As practicing neuroscientists, their feedback on my method was invaluable – especially in relation to the question of neuroanatomical term equivalence across articles.

conceptualised as mental imagery or hallucinations. By limiting the analysis to those brain regions implicated in greater than 35% of articles in each set, four *ROI (regions of interest)* were identified for further analysis (Table 8): the superior temporal gyrus (STG), the inferior frontal gyrus (IFG), the inferior parietal lobe (IPL), the middle frontal gyrus (MFG). Each of these ROI has a listing in Appendix 1 (Annotated Glossary) that details their neuroanatomical boundaries and the decisions I made in relation to the occasional ambiguities between various subsidiary and overlapping anatomical and functional regions. I identified how each article could be collected into one or more 'ROI-subset' of articles – as experiments typically investigated multiple brain regions, the articles in these subsets partially overlap. By combining the systemic selection of the articles reviewed with a systematic content-analysis approach I was therefore able to identify a sample of research articles reporting equivalent localised neural activity as correlating with experiences of both mental imagery and hallucinations.

Table 8: Proportion of articles for each of the ROI selected for further analysis

	ROI Acronym	% of all articles	# in Set-M	% in Set-M	# in Set-H	% in Set-H
Superior temporal gyrus	STG	66%	12	52%	21	78%
Inferior frontal gyrus	IFG	60%	13	57%	17	63%
Inferior parietal lobule	IPL	44%	13	57%	9	33%
Middle frontal gyrus	MFG	46%	13	57%	10	37%

5.1.3 Step Three: Comparing Paradigmatic Examples of Concepts as Used

The methodological steps just described identified several brain regions that were repeatedly found to correlate with experiences of both mental imagery and hallucinations. As discussed earlier, this is unsurprising. Indeed, there is ongoing research into the degree of SLMP-neuroanatomical-correlate overlap between different conceptualisations of SLMP.[156] However, while a quantitative meta-analysis might help to identify the net similarities and differences between the findings from the articles in Set-M and Set-H, this is clearly beyond the current scope and would shed little light on the question at hand.[157] Instead, each of these ROI-subsets can be understood as offering a paradigmatic collection of published fMRI experiments where localised brain activity has been found to correlate with SLMP regardless of whether the investigation used the concept of mental imagery or hallucinations.

To identify patterns within these subsets of the overall data sets I again took a summative content-analysis approach. As Hsiu-Fang Hsieh and Sarah E. Shannon (2005, 1283, 1286) argue, in summative content-analysis patterns provide a way of interpreting the contextual meaning of the latent uses of specific textual content. One way of identifying patterns is to analyse how the uses of content change depending on differing variables (Hsieh and Shannon 2005, 1285). To this end, the *Dedoose* program was used to develop an additional set of 'option-list descriptors'. This series of options described variable attributes that were applicable to an article as whole. Consequently, several intersecting variables were identified in the experimental methods. These included experiments that measured an increase or decrease in the ROI activity relative to a non-SLMP baseline ('activity'); those that measured the degree of coupling between activity within the ROI and activity in other regions ('connectivity'); those that measured the activity or connectivity during the state of

[156] Note, this literature does not use the notion of SLMP. For an example, see Hill and Linden's (2013, 35) study where the neuroanatomical correlates of experiences of mental imagery and hallucinations were compared. These types of studies treat hallucinations (including non-pathological hallucinations) and mental imagery as distinct phenomena. This is consistent with the independent use of each of the concepts in the studies analysed in this research project.

[157] See Wager et al (2007; 2009) for a discussion of different methods for providing a quantitative meta-analyses of fMRI experimental findings, as well as some of the limitations of these various approaches. Also see Jacob Stegenga's (2011) explanation for why meta-analyses should only provide one of many measures when assessing causal knowledge-claims.

experiencing SLMP relative to a non-SLMP state (*SLMP state*); and those that measured the activity or connectivity in subjects with a tendency for experiencing certain SLMP compared to subjects who do not typically experience these types of SLMP *(SLMP trait)*. As some articles reported results for both activity and connectivity and/or for both state and trait conditions for SLMP, this resulted in an additional four overlapping subsets of articles within Set-M and Set-H (summarised in Table 9 across all four ROI).[158]

Table 9: Sorting article sets into overlapping subsets by type of investigation

	ACTIVITY	CONNECTIVITY
STATE	**Activity-state:** change in ROI activity correlates with SLMP state 87% of Set-M (n = 20) 30% of Set-H (n = 8)	**Connectivity-state:** degree of ROI connectivity correlates with SLMP state 30% of Set-M (n = 7) 22% of Set-H (n = 6)
TRAIT	**Activity-trait:** change in ROI activity correlates with trait of SLMP 30% of Set-M (n = 7) 48% of Set-H (n = 13)	**Connectivity-trait:** degree of ROI connectivity correlates with trait of SLMP 17% of Set-M (n = 4) 37% of Set-H (n = 10)

I then calculated the number of articles in each of the four ROI-subsets – as distributions across both Set-M and Set-H – in relation to each of these variables. For example, for each ROI-subset, those articles that reported a change in activity (increase or decrease relative to a baseline) in the same brain regions during experiences of either mental imagery or hallucinations were identified (via the application of *Dedoose* codes), entered into a ROI-spreadsheet, and further analysed using Excel's conditional formatting tools. The

[158] Each of these methodological-based subsets of articles included articles from all four of the ROI subsets.

results from calculating these non-exclusive analytical categories allowed comparison of the knowledge generated about the role of each of the four selected ROI in experiences of SLMP as investigated by different experimental techniques within each article set. This further stage in the analysis involved an additional round of coding. Existing codes where 'weighted' (as +1/-1/0) to indicate the relative increase, decrease, or 'no change', reported for the localised change of brain activity within each ROI.

During this process, the *Dedoose* program rendering of graphs, images, and tables of quantified results (included within the text of these research articles) was found to be inadequate for detailed analysis. For example, when the text-file of an article was viewed in *Dedoose,* the formatting of tables and other figures were often disrupted to the extent that the information appeared incomplete. In response to this limitation in the textual-analysis program, I supplemented the process of weighted coding with a close-reading of the hard-copies of each article. Following this additional step, relevant codes were then applied to the relevant sections within the *Dedoose* copies of these articles.

The results from this coding-process were then were summarised in Excel to display the spread of results for each subset of articles (see: Supplementary Tables, Set 2). In this way, I identified those articles that reported a comparable change in localised neural activity during experiences of either mental imagery or hallucinations. Of these, investigations into activity changes during the state of either mental imagery or hallucinations were found to be the most common combination of variables for all four of the article subsets. Based on this, I decided to focus a qualitative analysis on those articles where an increase in localised brain activity was reported during mental imagery (twenty articles)[159] or hallucinations (ten

[159] See: (Bien and Sack 2014; Bird et al. 2010; Bunzeck et al. 2005; de Borst et al. 2012; Diekhof et al. 2011; Ganis, Thompson, and Kosslyn 2004; Guillot et al. 2009; Halpern et al. 2004; Johnson and Johnson 2014; Just et al. 2004; Kaas et al. 2010; Kana et al. 2006; Lamm et al. 2007; Reddy, Tsuchiya, and Serre 2010; Rudner, Rönnberg, and Hugdahl, K 2005; Sato et al. 2004; Slotnick,

articles)[160] within each sub-set of articles. Building on this initial examination, all articles that reported correlations between each brain region and the trait of experiencing mental imagery (eight articles) or hallucinations (twenty-two articles) were also analysed. This core comparative-analysis was then contextualised by providing a briefer account, where relevant, of those studies that reported SLMP-neuroanatomical-correlates in each ROI as an indicator of group differences in experiences of either mental imagery (four articles) or hallucinations (twenty-one articles). Likewise, when relevant, I included a comparison between the minority of studies that reported SLMP-neuroanatomical-correlates in each ROI as involved in patterns of connectivity relevant to experiences of either mental imagery (six articles) or hallucinations (twelve articles).

This series of analyses focused on the knowledge-claims presented about the SLMP-neuroanatomical-correlates (as these emerged from various methodological approaches). To complement this focused series of analyses, I then conducted an additional comparison of all the articles in Set-M and Set-H. This additional analysis involved building on the earlier exploratory coding, with another round of directed coding: focusing on phrases where uses of the concept of mental imagery or hallucinations was evident. Then, the 'retroactive up-coding' tool in *Dedoose* was again used to collate over-arching 'code-families' based on the contextual meaning within which each concept was used.

The resulting code-families highlighted how the concepts of mental imagery or hallucination were each used in a range of contexts: within the description of the phenomena being investigated; as part of the experimental aim; during the experimental design and

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Thompson, and Kosslyn 2012; Wais et al. 2010; Weiler, Suchan, and Daum 2010; Zvyagintsev et al. 2013)

[160] See: (Kelly M.J. Diederen et al. 2010; Goetz et al. 2014; Ralph E. Hoffman et al. 2007; Raij et al. 2009; Shine, Halliday, et al. 2014; van de Ven et al. 2005; Vercammen et al. 2011; Zhang, Shi, et al. 2008; Wible et al. 2009).

methodological procedures; in framing the contribution of fMRI data to knowledge-claims; and justifying the relevance of experimental findings. By comparing Set-M and Set-H in relation to the use of each conceptualisation of SLMP in these various contexts, patterns of concept-use could be identified.

5.2 Initial Considerations for a Comparative Analysis of Concepts as Used

The comparative analyses developed from the method just outlined will be detailed in the following two chapters. Before turning to these, there are two general patterns that need to be considered. Firstly, it is important to note the similarities common to the fMRI techniques used to investigate SLMP-neuroanatomical-correlates in both Set-M and Set-H (i.e., regardless of how these types of SLMP are conceptualised). In providing this first point of context, I seek to demonstrate that the material elements of the neuroimaging experiments in Set-M and Set-H are comparable. Secondly, I would like to note some of the challenges I encountered when comparing each of the various sub-sets of articles drawn from both Set-M and Set-H.

5.2.1 Identifying Neuroanatomical Correlates for Sensory-like Mental Phenomena

Apart from the type of SLMP investigated (conceptualised as either mental imagery or hallucinations), the experiments documented by articles in Set-M and Set-H were otherwise comparable. Most obviously, they all used fMRI techniques. In addition to illustrating how Set-M and Set-H are comparable on this material level, a brief discussion of fMRI as a neuroimaging technique therefore provides valuable context.[161] It is particularly important to appreciate that fMRI is typically used to investigate correlations between experiences of

[161] This is far from comprehensive. For a list of those principles of fMRI commonly recognised by researchers, even when not made explicit in their publications, see: (Bechtel and Richardson 2010). For some historical accounts of neuroimaging and the role of this technique within the neurosciences, see (Borck 2016; Savoy 2001; Raichle 2000; Tovino 2007; Zago et al. 2012). Some technical terms are included in Appendix 1 (Annotated Glossary); also see fMRI training manuals (e.g., Bandettini and Moonen 2000; Filippi 2009).

mental phenomena and changes in localised neural activity. Firstly, as a non-invasive technology, fMRI is used to indirectly observe changes in neural activity within areas of the human brain (Ashby 2011). In the articles examined, the most common fMRI approach was to measure the blood oxygen level-dependent (BOLD) signal as it changed over time. The BOLD signal measures the ratio of oxygenated to deoxygenated haemoglobin molecules through the different magnetic properties when the binding sites for oxygen are either full or empty (Ashby 2011, 3). The theoretical assumption for interpreting this ratio draws on a wide collection of scientific knowledge: including the relationship between cerebral blood flow and metabolic processes; the development of radiotracer techniques; the measurements of the changing magnetic properties of blood; and the proposal that changes in neuronal activity generate a local change in the amount of oxygen within tissue (Pauling and Coryell 1936; Logothetis 2002; Zago et al. 2012). When drawn together, these developments support the following series of assumptions: that an increase in neuronal activity results in an increase in metabolism demands; that this results in an increase in consumption of oxygen; that this increase changes the ratio of oxygenated-to-deoxygenated haemoglobin in the venous system surrounding the tissues in question; and that this change can be measured by the relative distortion of a magnetic field in an MRI machine (Ashby 2011, 3; Zago et al. 2012, 20).

In this way, BOLD signals from individual fMRI experiments provide evidence about changes in neural activity; they do not provide evidence of mental processes (Wager, Lindquist, and Kaplan 2007, 150). To use this fMRI data for investigating the neural mechanism involved in mental processes, various experimental conditions are designed to isolate selected mental processes and establish a specific brain-behaviour correlation. That is, a correlation between: a) the mental processes isolated by the behaviour during the experimental condition; and, b) the change in neural activity measured during the experimental condition. While these experimental conditions are extremely varied (as detailed later), all presuppose that it is possible to locate the region(s) of the brain within which neuronal activity manifests in a way that corresponds with the mental process the test-subject is experiencing. Within this context, the neural activity is measured relative to a baseline condition to identify any statistical differences in the pattern of neural activity as it correlates to the mental process isolated in the experimental condition.

Once the relative change in regional brain activity during the baseline and the experimental condition(s) are measured, the baseline measurement can be subtracted from the various experimental measurements to allow comparisons between experimental conditions or between separate groups of subjects. For example, the change in regional brain activity measured during one experimental condition can be compared to the neural activity measured during other experimental conditions within the same group of subjects. Alternatively, the relative change in regional brain activity can be measured during an experimental condition across a group and then compared to the relative change in neural activity calculated during the same experimental condition across a different group of subjects. These approaches rest on the notion that "it should be possible to identify the neural correlates of specific processes by contrasting experimental conditions that are carefully selected to vary with respect to only a key process of interest" (Poldrack and Yarkoni 2016, 589).

Based on this approach, many experimental conditions are designed with the expectation that a given task requires a subject to engage the mental process of interest (and can be compared to another task that does not engage that mental process). However, even when there is a correlation between the experimental task and specific changes in neural activity, any claim about the mental process conflates the latent construct with the latent measures (based on the assumption that the task does indeed engage the mental process of interest) (Poldrack and Yarkoni 2016, 590). As with most experimental conditions, this subtraction model ignores a range of real-world variables to investigate a specific variable within idealised conditions. As such, while the problems with subtractions models are widely recognised, there is still a tendency to conflate experimental manipulation with the mental processes that the experimental condition attempted to isolate (Poldrack and Yarkoni 2016, 589).

This description of experimental fMRI techniques is partial and obscures a range of important variations. Rather than a comprehensive survey, my focus seeks to highlight important aspects of fMRI techniques that are shared by those experiments documented in both Set-M and Set-H.

5.2.2 Methodological considerations

As gestured towards earlier, there were several variables that needed to be considered throughout my comparative analysis of Set-M and Set-H. For the sake of clarity in the following chapters I will briefly discuss the following interrelated considerations: region of interest (ROI); identifying SLMP-neuroanatomical-correlates; inferring mental processes from fMRI data; and contextualising initial differences between the article-sets.

The localised changes in neural activity measured in fMRI experiments are often reported in terms of macroanatomy (Nolte and Angevine 2013, 841–53). As mentioned earlier, terminology varies widely in these practices. In addition to the difficulties discussed earlier, details such as laterality (whether the activity was in the ROI bilaterally or just within the left or right hemisphere) are often not reported. Given the importance placed on laterality, I have included this information where available and, if no laterality information was provided, the activity has been taken as bilateral for the ROI in question.[162]

[162] This unmarked bilateral activation assumes that not reporting lateralisation information indicated bilateral measurements rather than imprecise reporting.

In addition to these challenges, there are also several different strategies for identifying anatomical regions in individual subjects – each of which has a constellation of advantages and disadvantages. One approach is to define the anatomy of the ROI based on the peak areas of signal measured during a whole-brain voxel-wise analysis (Poldrack 2007, 67–70). This approach can be useful for exploratory studies of the different patterns of activity across multiple conditions; however, it is of limited use for statistical analysis. Therefore, in order to increase statistical power, experimental designs often limit the research analysis to changes in activity within pre-defined anatomical regions (Bluhm 2011, 322). Unfortunately, while increasing tractability for statistical analysis and reducing the problem of false-negative results, limiting an experiment to investigating pre-defined ROI increases the chance of false-positive errors (Bluhm 2011, 322).

Despite the difficulties, pre-defined ROI analyses have proved a popular approach within neuroimaging experiments. This is reflected in the documented experiments in both Set-M and Set-H. These pre-defined ROI tend to be chosen based on those brain regions previously related to the neurocognitive process of interest to the investigation. The ROI in question may then be identified (in the brain scans of experimental subjects) based on anatomical criteria identified in relation to atlas-based macroanatomy or stereotaxic coordinates (Poldrack 2007, 68). However, an alternative way of pre-defining ROI is to identify the individual anatomical regions of functionally relevant brain regions. In this approach, the subject-specific anatomical regions are identified as the region where a cluster of voxels correlate to the function in question (Poldrack 2007, 68). For example, to identify the auditory-cortex, an initial scan could be used to localise the anatomical region that responds to auditory stimuli in an individual.

Regardless of whether ROI were defined prior to the experiment or emerged within the experiment, the reported activity in each region typically located this activity in macroanatomical terms (while only sometimes detailing various mesoanatomical locations within these). This practice is unsurprising given that the boundaries of specific mesoanatomical regions can vary considerably in different contexts. This variability is illustrated well by Terence R. Anthony's (1994, 587) report that – in a survey of twenty-five neuroscientific textbooks – the outer boundaries of 'Wernicke's area' varied from text to text. Another example is the difference in the number and size of individual areas specified within the parietal lobe found when comparing existing maps for brain regions (Siegel et al. 2008). Given these difficulties, macroanatomical ROI provide key terms in both identifying localised neural activity during a given experimental condition and documenting experimental results in associated publications. As detailed earlier, I will be following this convention in the later analyses.

In both Set-M and Set-H, articles documented a change in activity during a specified experimental condition (that related to experiences of SLMP) relative to a baseline (that was not related to experiences of SLMP). Unless otherwise stated, this is what is indicated by the term SLMP-neuroanatomical-correlate. The term 'baseline' will therefore be used to refer to whatever standard an experiment used to measure the change in neural activity within each individual subject (whether a rest period, no-task, or control condition during which experiences of SLMP were not reported). Likewise, unless indicated otherwise 'activity' will be used to indicate a change (increase or decrease) in the BOLD signal relative to the signal recorded during a baseline.

These SLMP-neuroanatomical-correlates were dutifully reported by articles in both sets. However, just because a SLMP-neuroanatomical-correlate was reported for a given ROI did not mean that this experimental finding would be discussed in any detail. In some cases, the experimental focus was a different ROI. In other cases, the experimental focus was on the degree to which these initial SLMP-neuroanatomical-correlates differed relative to changes in similarly localised neural activity correlated with alternative experimental conditions.

Take the articles in the MFG ROI-subset for example: all twenty-three articles reported an increase in MFG activity as correlating with experiences of SLMP conceptualised as either mental imagery or hallucinations. However, of these, only 22% were principally interested in these SLMP-neuroanatomical-correlates. Some articles (13%) did not even discuss the SLMP-neuroanatomical-correlates that they reported within the MFG; focusing instead on the SLMP-neuroanatomical-correlates located in other ROI. Meanwhile, the majority of articles (65%) focused on comparing the SLMP-neuroanatomical-correlates located within the MFG with similarly localised neuroanatomical correlates isolated by another (non-SLMP) experimental condition. In the following analysis I will focus on the reported SLMP-neuroanatomical-correlates and indicate the ways in which additional experimental results relate to this.

As noted earlier, inferring that regions of localised brain activity underlie specific mental processes involves another step. To link the change in regional brain activity to a specific mental process, a connection needs to be drawn between the region in which the brain activity was measured and the mental process in question. One way to do this is to make a 'forward inference' by comparing the difference between the patterns of observed brain activity in two or more experimental conditions and inferring that the difference in activity patterns relate to differences in the neural mechanisms that underlie the mental experience isolated by each condition (Henson 2006). In addition, a 'reverse inference' is sometimes used to reason backwards from an experimental finding of activation in a particular brain region (during a given condition) to implicate the engagement of a particular cognitive function that the existing literature has previously associated with that brain region (Poldrack

2006). Although common, 'reverse inferences' have become an increasingly contentious practice (Poldrack 2011; Machery 2014; Glymour and Hanson 2015).

In addition to specific questions about reverse inference, the use of neuroimaging experiments to generate knowledge about the underlying mechanisms of mental processes has received criticism more generally. Firstly, the practices used to relate brain function to neuroanatomy have long been questioned (Fox and Friston 2012; J. B. McCaffrey 2015; Mundale 2001). On top of this, there remain numerous difficulties associated with designing experimental conditions that isolate any given mental process of interest (Wager, Lindquist, and Kaplan 2007; Poldrack and Yarkoni 2016; Stoyanov, Machamer, and Schaffner 2013). Likewise, there are a range of unresolved problems with inter-subject variability (Poline, Thirion, and Meriaux 2010; Cui et al. 2007, 477). For example, fMRI data generally indicates that inter-subject variability is generally greater than intra-subject variability (Thirion et al. 2007, 105). Furthermore, the difficulties these unresolved questions pose for group comparisons are further compounded by the number of subjects in fMRI experiments often being lower than that recommended (n >20) for achieving results that are both sensitive and reliable (Thirion et al. 2007, 117). For instance, individual variability raises the possibility that the practice of defining homogeneous groups of study-participants (to stabilise experimental data) limits applicability of experimental knowledge in the context of the heterogeneous populations that these groups are taken to represent (Huber and Kutschenko 2009, 309).

These difficulties with fMRI experimental research all relate to standard methodological and disciplinary practices that are common to most neuroimaging research. To account for this, the experiments documented by articles in Set-M and Set-H were matched in terms of fMRI experimental protocols as much as possible. In each case, fMRI techniques are used to provide an indirect measurement of regional brain activity that, when reported as located in specific neuroanatomical regions and carefully correlated to experimental conditions that isolate a given mental phenomena, is used to implicate specific brain regions in the neurocognitive mechanisms thought to underlie that mental phenomena. Therefore, the documented accounts of neuroimaging experiments examined can be considered to all share the limitations raised by the unresolved questions of the material-elements contributing to neuroimaging research. Given this, I will start with the assumption that SLMP-neuroanatomical-correlates are considered evidence that can contribute to accounts of the underlying neurophysiological processes that explain mental experiences such as mental imagery or hallucinations.

As mentioned earlier, articles in both sets frequently reported that a change in the activity and/or connectivity of a specific ROI correlated with the state of experiencing SLMP and/or the trait of experiencing SLMP. However, investigations into the role of ROI during the state of experiencing SLMP were much more common in articles from Set-M. In contrast, articles in Set-H were more likely to report investigating the role of ROI in the traits that predispose hallucinations.

These differences in approach can be understood in light of comments within Set-H. These comments described the state of experiencing a given mental phenomena as an option that, while preferred, presented too many difficulties to studying hallucinations. Indeed, drawing on the characterisations of hallucinations outlined in Chapter Three this difficulty was typically attributed to the unreliability of a hallucinating subject's judgment as to their own mental process. For example, van de Ven et al. (2005, 652) commented that subject reports as to the presence or absence of hallucinations could not be relied upon because hallucinations are characterised by a confusion as to the source of these SLMP. Alternatively, even when subjects were considered capable of reporting on the presence/absence of their hallucinations, there was a tendency to investigate the predisposition to hallucinate in preference to the experience itself. For example, in a study by Hoffman et al. (2011, 408) patients were considered capable of distinguishing between the presence and absence of their hallucinations and yet their reports were excluded from the main analysis. This exclusion was justified by the possibility that – due to the inability to provide a comparable monitoring condition for the control group – results obtained from discrete hallucinatory experiences might obscure the aim of investigating the "pre-emergent causal factor" underlying hallucinations (Ralph E. Hoffman et al. 2011, 411). Given this context, I have included both state and trait studies in the following analysis and will indicate which type of study is being discussed when relevant.

A related consideration is highlighted by the different proportions for each type of modality investigated in each set. As mentioned earlier, articles from Set-M and Set-H both include experiments investigating visual and/or auditory SLMP. However, of the twenty-three articles in Set-M, 70% investigated visual imagery exclusively, 17% investigated auditory imagery in relation to visual imagery, and only 13% investigated auditory imagery exclusively. Conversely, of the twenty-seven articles in Set-H only 22% investigated visual hallucinations, 4% examined both auditory and visual hallucinations, and the other 74% investigated auditory hallucinations exclusively.

The contrasting modality-specific focus of these two sets of articles sits at odds with commonly reported experiences of both mental imagery and hallucinations. As discussed in Chapter Three, SLMP have been reported in a wide variety of separate sensory modalities as well as in various combinations of multi-modal experiences. Nonetheless, this focus on single-modality experiences is in line with historically contingent trends (discussed in Chapter Four): scientific interest increasingly concentrated on either the visual modalities of mental imagery or the auditory modalities of hallucinations.[163] With this in mind, I will indicate when within-modality and between-modality comparisons are being made in the following analysis.

Likewise, although both Set-M and Set-H included within-group and between-group studies the proportion of between-group studies was greater in the Set-H. In within-group experiments all the fMRI scans acquired during an experimental task for a specific subject group were compared with all the fMRI scans acquired during comparative tasks within the same group of subjects. For between-group experiments all subjects were given the same task(s) and all the fMRI scans acquired during these tasks were compared for each different group of subjects. However, the experimental tasks given to subjects cut-across experiments regardless of whether they were within-group or between-group comparative studies. In each case, the comparative experimental data – relative changes in neuroanatomical activity between two experimental conditions – was typically reported in terms of the fMRI scans acquired during the main task as these related to the fMRI scans during the comparative condition. It is for this reason that both within-group and between-group studies have been included in the analysis and this difference will be indicated when relevant: for the sake of clarity, when discussing these experimental results, I will refer to the relative change in activity and detail the comparative condition in question.

With these clarifications in hand, these variations can be accounted for within a focus on those articles that reported equivalent SLMP-neuroanatomical-correlates (within both visual and auditory modalities) from both Set-M and Set-H of the documented experiments. I outlined my approach to this earlier and I will discuss it again in in Chapter Seven. For now, it is enough to appreciate that all the articles communicated the results of their experiments

[163] While this view has dominated since at least the 1960s (Landis and Mettler 1964, 115), see Chapter Three for more on the slow shifts in clinical approaches to 'hearing voices' – potentially an emerging concept in its own right. This shift was not apparent in the sampled set of published neuroimaging experiments from 2004-2014.

in terms of correlations between experiences of SLMP and the localised changes in neural activity (measured as the BOLD signal during an fMRI scan). These SLMP-neuroanatomical-correlates were reported in ways that could be compared across multiple types of comparative conditions, experimental tasks, and aspect of experiencing SLMP investigated.

Therefore, despite these various challenges, it was still possible to compare the articles from Set-M and Set-H for the four ROI found to be most frequently reported as relevant to both mental imagery and hallucinations. As summarised earlier, these comparisons focused on articles within four ROI-subsets (that each documented similar SLMP-neuroanatomical-correlates identified by fMRI experiments regardless of whether the SLMP were conceptualised as mental imagery or hallucinations). For each of these I will concentrate on demonstrating that these similar SLMP-neuroanatomical-correlates were reported by experiments investigating the state of experiencing both mental imagery and hallucinations of the same modality.

When relevant to this main comparison, I will include discussions of those reports of similar SLMP-neuroanatomical-correlates within other experimental conditions. In doing so, I aim to highlight additional trends within and between Set-M and Set-H that contextualise the disconnected knowledge-claims that diverge from similarly reported SLMP-neuroanatomical-correlates. Across all four of ROI-subsets these accompanying trends will provide examples of increases in localised activity that are of interest for multiple reasons: as relative changes in comparison to another experimental condition; as relative changes between groups; and as coupled with activity in other ROI in investigations of connectivity relating either to the state or to the trait of experiencing SLMP. By including examples of these smaller trends, I intend to illustrate that the disconnection between the knowledge-claims generated by articles within Set-M and Set-H is consistent across these variable approaches.

5.2.3 Independent Uses of Interdependent Conceptual Tools

Taking these considerations into account, Set-M and Set-H can be compared in terms of how SLMP-neuroanatomical-correlates localised to the same ROI can contribute to diverging knowledge-claims about the mechanisms underlying experiences of either mental imagery or hallucinations (each investigated as a distinct type of SLMP). At this point, it is worth foreshadowing how comparing the articles in Set-M and Set-H provides additional support for two points that I developed earlier in this thesis: that the concepts of mental imagery and hallucinations are used independently of each other (Chapter Three); and that their inverse sets of typical characteristics stem from interdependent historical foundations (Chapter Four).

Firstly, over 85% of the articles used the concept of either mental imagery or hallucinations without even mentioning the other concept. In addition, even in those articles where mental imagery and hallucinations were both discussed, the experiences of SLMP conceptualised in these ways were treated as distinct (and, as such, able to be investigated independently of each other). For example, often one concept individuated the experience of SLMP of interest while the other was mentioned in passing as merely one of a number of other types of experiences of secondary interest: hallucinations were mentioned alongside other types of experiences that might involve mental imagery, while imagery was mentioned alongside other ordinary functions that might – if disrupted – cause hallucinations (e.g., Ralph E. Hoffman et al. 2011; Sato et al. 2004).

Secondly, the inverse characterisation of mental imagery and hallucinations featured whenever these two concepts were distinguished from each other. For example, van de Ven et al. (2005, 645) noted that "Mental imagery is typically distinguished from the experience of hallucinations in terms of vividness and degree of control that one can exert upon the percept". Similarly, Vercammen et al. (2011) implicitly differentiated between cases where people use inner-speech (silently 'talking' to themselves), and cases where people are "imaging performing mental auditory imagery", and experiences of AVH that "sound like real voice" with the perceptual quality of 'loudness' and 'reality'. Indeed, experiences of mental imagery and (auditory-verbal) hallucinations were assumed to be distinct even when positioned as potentially related. For example, one article described verbal hallucinations as "a specific sort of mental auditory imagery" (Bunzeck et al. 2005, 1124), another article drew on the hypothesis that hallucinations result from misattributing the source of self-generated imagery (Vercammen et al. 2010). No attempt to explain the distinction between mental imagery and hallucinations was made in either case.

With these similarities in mind, the following two chapters will focus on the differences between those fMRI experiments documented in either Set-M or Set-H. Following the methodological steps outlined above, I will examine how knowledge-claims generated in fMRI experiments can depend, in part, on the conceptualisation used to individuate those experiences that the experiment is designed to investigate (Chapter Six). I will then turn to examining how the entrenched associations that structure the uses of these two concepts for investigating experiences of SLMP in terms of either function or dysfunction can contribute to knowledge-claims that diverged from similar experimental findings (Chapters Seven). Based on these analyses, I will argue that the concept used to investigate SLMP contributes to the knowledge-claims generated from SLMP-neuroanatomical-correlates. Finally, in Chapter Eight I will draw on the theoretical approach developed in Chapter Two to clarify the connection between this analysis and the context provided by Chapters Three and Four. Positioned in this way, I will demonstrate that the concepts of mental imagery and hallucinations are each structured for use as independent tools for pursing specific goals in experiments. Building on this, I will argue that these structured tools can actively contribute to the knowledge generated by neuroimaging experiments.

6 Neuroanatomical Correlates for Mental Imagery and Hallucinations

Following the procedure outlined in Chapter Five, I collected a selection of articles documenting fMRI experiments. Each experiment identified a SLMP-neuroanatomical-correlate: a correlation reported between localised neural activity and experiences of SLMP conceptualised as either mental imagery (Set-M, n = 23) or hallucinations (Set-H, n = 27). As explored in the following chapters, comparing these sets of articles highlights that neuroimaging experiments investigating the underlying neurophysiology of either mental imagery or hallucinations can generate differing knowledge-claims based on equivalent SLMP-neuroanatomical-correlates.[164] In this chapter, I will focus on detailing a comparative analysis of those articles that reported SLMP-neuroanatomical-correlates located within the STG, the IFG, the IPL, and/or the MFG regions of the brain. To this end, in the next section I will discuss each of these four regions independently, and then examine their relevance more generally.

6.1 Locating SLMP-neuroanatomical-correlates

As detailed in Chapter Five, the articles that reported SLMP-neuroanatomical-correlates in each of these four ROI each provide paradigmatic examples of published fMRI experiments where localised brain activity has been found to correlate with SLMP regardless of whether the phenomena experienced was conceptualised as mental imagery or hallucinations. Comparing the SLMP-neuroanatomical-correlates reported for each of these ROI across the articles in Set-M and Set-H reveals two interconnected points. The first point is that this specific difference stems from a similarity; with several similar SLMP-neuroanatomical-correlates reported regardless of whether the SLMP experiences were conceptualised as

[164] Following on from the discussion in Chapter Five, *knowledge-claims* can be taken to mean first-order knowledge claims unless otherwise specified – see Appendix 1 (Annotated Glossary).

mental imagery or hallucinations. The second point is that these equivalent SLMP-neuroanatomical-correlates were repeatedly reported as relevant to understanding the *unique* experience of either mental imagery or hallucinations.

To clarify these two points, this Chapter will focus on offering some detailed examples. This will exclude a range of alternative explanations for the differences between the articles in Set-M and Set-H. Finally, drawing support for these two points together I will argue that documented neuroimaging experiments can report similar SLMP-neuroanatomical-correlates in support for diverging knowledge-claims; a divergence that hinges on whether the type of SLMP investigated was conceptualised as mental imagery or hallucinations.

6.1.1 Superior Temporal Gyrus

I will begin with those articles that reported localising SLMP-neuroanatomical-correlates within the Superior Temporal Gyrus (STG).[165] This includes articles where the type of SLMP investigated was conceptualised as either mental imagery (twelve articles in Set-M) or hallucinations (twenty-two articles in Set-H). For articles within the STG ROI-subset, the most frequent similarity between Set-M and Set-H relates to a localised increase in STG activity as it correlated to the state of experiencing auditory SLMP. Within Set-M, this included five articles that were interested in increases in STG activity during the state of experiencing auditory mental imagery (Bunzeck et al. 2005; Halpern et al. 2004; Rudner, Rönnberg, and Hugdahl, K 2005; Sato et al. 2004; Zvyagintsev et al. 2013). Similarly, an increase in STG activity during the state of experiencing auditory hallucinations was of interest in five articles within Set-H (Kelly M.J. Diederen et al. 2010; Ralph E. Hoffman et al. 2007; Raij et al. 2009; van de Ven et al. 2005; van Lutterveld et al. 2014).

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[165] The neuroanatomical bounds of the *STG (superior temporal gyrus)* region are detatiled in Appendix 1 (Annotated Glossary); also see Set 2: ROI Analysis in Appendix 2.

This similarity in reported SLMP-neuroanatomical-correlates in experiments using the concepts of mental imagery or hallucinations persists even when considering the variety of STG subregions. Indeed, while there were differences, the reported changes in activity within STG subregions were broadly similar across both sets of articles.[166] For example, increased activity during auditory experiences of both mental imagery and hallucinations were specifically reported for the left transverse temporal gyri and the posterior part of BA22. This includes reports of increased STG activity during auditory imagery, with more finely localised activation reported within the left transverse temporal gyrus (Zvyagintsev et al. 2013) and posterior part of BA22 bilaterally (Bunzeck et al. 2005; Rudner, Rönnberg, and Hugdahl, K 2005; Zvyagintsev et al. 2013).

The left transverse temporal gyrus and bilateral posterior STG were also repeatedly specified in the articles from Set-H. For example, there were specific reports that experiences of auditory hallucinations correlated with bilateral increases in activity in the transverse temporal gyrus (Kelly M.J. Diederen et al. 2010; van de Ven et al. 2005); with increased activity in the left anterior transverse temporal gyrus (Ralph E. Hoffman et al. 2007; Raij et al. 2009); increased activity in the left posterior part of BA22 in the STG (Ralph E. Hoffman et al. 2007); and increased activity in the right posterior part of the STG (Raij et al. 2009).

These correlations, between increased activity within the STG and experiences of auditory SLMP, contributed to diverging knowledge-claims in the articles from Set-M and Set-H; these differing knowledge-claims contrast sharply with the similarities just detailed. Firstly, within Set-M, increases in STG activity observed during auditory SLMP contributed

[166] These differences were that the reported STG activation during auditory experiences were reported in the left anterior part of BA22 in the STG during specific aspects of auditory-verbal imagery in four articles (Halpern et al. 2004; Rudner, Rönnberg, and Hugdahl, K 2005; Sato et al. 2004; Zvyagintsev et al. 2013); there were no specific reports for this subregion within the activity studies of auditory hallucinatory states.

to knowledge-claims about the relationship between different modalities of mental imagery and perceptual processes. For an example, Halpern et al. (2004, 1290) took their finding – that increased activity in the posterior STG during auditory mental imagery was greater than that during visual imagery – as evidence that there may be modality-specific neural substrates underlying imagery within primary sensory cortices. Likewise, Bunzeck et al. (2005, 1125) took their observation – that mental imagery of complex sounds correlated with increased activity in the posterior STG (but not the transverse temporal gyrus) – as providing another piece of "evidence that perception and mental imagery of complex sounds rely on overlapping but dissociable neuroanatomical correlates". Similarly, for Zvyagintsev et al. (2013, 1431) their observation – of increased activity in the posterior STG during auditory-verbal imagery (and not visual imagery) – was taken as an indication that there are modality-specific neurophysiological processes underlying experiences of mental imagery.

Whereas, within Set-H, increased activity in the posterior STG during experiences of auditory hallucinations contributed to quite different knowledge-claims: about the mechanisms underlying the role of hallucinations as a psychiatric symptom; as support for treatment options; or as an example of methods useful for investigating hallucination pathology. As an example of the first of these, the observation of an increase in posterior STG activity during hallucinatory experiences – by Raij et al. (2009) – provided an opportunity to examine the relationship between this neural activity and individual scores on the clinical scale of the Subjective Reality of Hallucinations (SRH). Following this examination, Raij et al. (2009, 2999) reported that they did not find a correlation between the level of increased STG activity and the SRH scores of subjects. Adapting to this unexpected result, the investigation went on to calculate a correlation between the SRH score and the connectivity between STG activity and activity changes in other brain regions. From this, Raij et al. (2009) reported that coupling between the increased activity within the STG and the IFG was greater when subject's SRH scores were highest. As an example of investigating treatment options, Hoffman et al. (2007, 2737) took the observation of increased activity in the posterior STG during auditory hallucinations as justification for selecting this region for testing an experimental treatment for hallucinations (that involved repetitive transcranial magnetic stimulation (rTMS)). However, in testing this proposal, Hoffman et al. (2007, 2741) went on to suggest the more general knowledge-claim that Wernicke's area (within the STG) plays "a direct role in generating or expressing AVHs in dextral patients". Finally, as an example of improving the methods of investigating the pathology of hallucinations, van de Ven et al. (2005, 654) took the variability of STG activity recorded during hallucinations to suggest that the detection of activity in this region may relate to the length of the hallucination episodes; proposing that a data-driven approach "has the potential to identify these activity patterns without the necessity of any model of activity".

So far, this comparison illustrates that when increases in STG activity correlate with experiences of auditory SLMP these findings have been reported as support for a range of disconnected knowledge-claims. In addition, the pattern of these various knowledge-claims diverges when it comes to relating the SLMP-neuroanatomical-correlates localised within the STG to the neurophysiological mechanisms that underlie either mental imagery or hallucinations. To recap, firstly, when increased activity within the STG was correlated with experiences of auditory mental imagery these experimental findings contributed to knowledge-claims about the role of this ordinary experience within the complex relationships between various cognitive functions (specifically, other modalities of mental imagery and auditory perception). In contrast, when experiences of hallucinations were correlated with similar increases in STG activity, these experimental findings contributed to knowledge-claims about the dysfunctional activity responsible for hallucinations. For example, knowledge-claims positioned this dysfunction as relevant to better understanding hallucinatory symptoms, improving treatment for hallucinations, or improving investigations into of the neuroanatomical mechanisms underlying hallucinations.

A related pattern is also suggested by the few articles that reported a correlation between increased STG activity and visual SLMP in experiments investigating either visual imagery (nine articles from Set-M) or visual hallucinations (three articles from Set-H). Within Set-M, the relevance reported for the change in STG activity during visual SLMP varied: reported as overlapping completely with the increased STG activity measured during visual perception (Ganis, Thompson, and Kosslyn 2004); reported as relatively small when compared to the increases in STG activity during auditory imagery (Halpern et al. 2004; Zvyagintsev et al. 2013); and reported as negatively coupled with activity in other ROI when compared to STG connectivity during 'language-based thought' (Doucet et al. 2012).[167] There was a similar range of variability within Set-H: one reported an increase in STG activity during visual hallucinations as less than the increase in STG activity during a non-hallucinating baseline period (Goetz et al. 2014); another reported a smaller increase in STG activity in patients with visual hallucinations than patients without visual hallucinations (Ramírez-Ruiz et al. 2008); and another reported that STG activity was negatively coupled with activity in other ROI for patients with visual hallucinations (compared to those with both auditory and visual hallucinations) (Amad et al. 2014).

Compared to those experiments that investigated correlations between increased STG activity and auditory SLMP, there are less direct similarities between the experimental findings reported for visual imagery and visual hallucinations. However, those similarities that are there also emphasise the disconnection between the knowledge-claims that these

[167] Note that in Doucet et al. (2012) 'language-based thought' is juxtaposed with visual imagery specifically rather than imagery generally (and, as such, might have involved experiences of auditory-verbal imagery in some subjects).

broadly similar experimental findings helped to generate. For example, when correlations between increases in STG activity and visual SLMP were reported as relatively small compared to other experimental conditions the knowledge generated differed depending on how the SLMP were conceptualised. Within Set-H, the correlations experiments generated between relatively small increases in STG activity and visual SLMP were largely ignored. Instead, emphasis was placed on those experimental findings that more clearly contributed to the proposal that hallucinations result from failure of 'top down processing' (Ramírez-Ruiz et al. 2008; Goetz et al. 2014). The one exception to this was a report that lower degrees of STG connectivity in patients with visual hallucinations (compared to those with both auditory and visual hallucinations) indicated that modality-specific processes underlie the pathological dysconnectivity responsible for hallucinations (Amad et al. 2014). In contrast, within Set-M correlations between relatively small increases in STG activity and visual SLMP contributed to a range of knowledge-claims. In some cases, the correlation between relatively small increases in STG activity and visual imagery (as compared to auditory imagery) were taken as indicative that modality-specific mechanisms are involved in mental imagery (Halpern et al. 2004; Zvyagintsev et al. 2013). Alternatively, a lower degree of STG connectivity during imagery (compared to 'language-based thought') was reported as consistent with the hypothesis that internally oriented thoughts are favoured during resting mental states (Doucet et al. 2012, 3198). Furthermore, even when the reported results of correlations between increased STG activity and visual SLMP within Set-M were sidelined (as they were in Set-H), the focus remained on neurocognitive function. For example, correlations between increased STG activity and experiences of visual SLMP were frequently reported as consistent with earlier studies and so overshadowed by findings considered more relevant to the experimental aim of investigating relationships between mental imagery and either memory or attention (e.g., Bird et al. 2010; de Borst et al. 2012; Weiler, Suchan, and Daum 2010).

This comparison demonstrates that, unless sidelined entirely, the knowledge-claims generated from reports of a correlation between a relatively small increase in STG activity and visual SLMP typically differed depending on whether these experiences of SLMP were conceptualised as mental imagery or hallucinations. In addition, even when the knowledge-claims could be considered potentially related, they remained disconnected. This was particularly evident in the parallel proposals that modality-specific mechanisms underlie experiences of SLMP. In each case, these proposals were generated from experiments where increases in STG activity for SLMP were found to be lower for experiences in the visual modality than those in the auditory modality. However, these findings were framed differently depending on whether the various SLMP were conceptualised as mental imagery or hallucinations. In the case of mental imagery, differences between modalities were considered relevant to understanding the role of mental imagery in cognitive function. In contrast, the possibility that modality-specific mechanisms underlie hallucinations was proposed to contribute to knowledge about the dysfunction underlying hallucinations.

These patterns echo those described for the disconnected knowledge-claims proposed in relation to the correlations measured between increased STG activity and auditory SLMP. For both modalities, experimentally generated units of knowledge about the STG were proposed to explain either the role of mental imagery in cognitive function or the role of hallucinations as symptoms of illness. As such, similar SLMP-neuroanatomical-correlates were reported in experiments regardless of both the modality of SLMP investigated and the concept used to investigate these SLMP experiences. Furthermore, the type of knowledge-claim generated from these SLMP-neuroanatomical-correlates depended on the conceptualisation of SLMP rather than the modality of SLMP investigated. In this way, similar experimental findings can be seen to have contributed to disconnected types of knowledge-claims (about functional or dysfunctional neurocognition) that diverged from similar SLMP-neuroanatomical-correlates (increased STG activity correlating to experiences of SLMP) depending on the concept used for investigating SLMP (mental imagery or hallucinations).

6.1.2 Inferior Frontal Gyrus

A brief comparison of those articles that reported localising SLMP-neuroanatomical-correlates within the Inferior Frontal Gyrus (IFG) highlights trends consistent with those detailed for the STS ROI.[168] Most strikingly, increased IFG activity was reported during the state of experiencing auditory SLMP regardless of whether these experiences were conceptualised as mental imagery (thirteen articles in Set-M) or hallucinations (sixteen articles in Set-H).

Starting with Set-M, bilateral increases in the IFG were reported during auditory-verbal experiences, with peak activity found in Broca's area in the left frontal operculum (Rudner, Rönnberg, and Hugdahl, K 2005; Sato et al. 2004). In relation to this, Rudner et al. (2005) also reported an additional increase in the right hemisphere IFG (specifically, in the pars opercularis (BA44) within Broca's area) during the manipulation of auditory images when compared to activity in the same region during the process of generating imagery.

Likewise, in Set-H, an increase in IFG activity was repeatedly correlated with the state of experiencing AVH (Kelly M.J. Diederen et al. 2010; Ralph E. Hoffman et al. 2007; Raij et al. 2009; Wible et al. 2009). In relation to this, increased activity within Broca's area (in the left frontal operculum) was also of particular interest (Kelly M.J. Diederen et al. 2010; Ralph E. Hoffman et al. 2007). In addition, although also reporting increased IFG activity during

[168] The neuroanatomical bounds of the *IFG (inferior frontal gyrus)* region are detatiled in Appendix 1 (Annotated Glossary); also see Set 2: ROI Analysis in Appendix 2.

hallucinatory experiences, Vercammen et al., (2011) focused on investigating whether the typical characteristics of hallucinations were relevant to their underlying mechanisms. In relation to this, the results of the experiment included reports that the degree by which IFG activity decreased during experiences of 'inner speech' correlated with higher 'loudness' scores for auditory-hallucinations (Vercammen et al. 2011).[169]

Despite similar correlations between increased IFG activity and experiences of auditory SLMP being reported regardless of the concept used to investigate these experiences, these experimental findings contributed to a range of disconnected knowledge-claims. Furthermore, this range of knowledge-claims diverged in accordance with how the SLMP experience was conceptualised. In this way, these diverging knowledge-claims hinged on a key variable within the heterogeneous interactions contributing to these experiments: the conceptualisation of the type of SLMP experience being investigated.

Specific examples from both articles sets further illustrate how using the concepts of either mental imagery or hallucinations functioned as a pivotal contribution to the knowledge that these experiments generated about the role of the IFG in neurocognitive function/dysfunction. Firstly, within Set-M, reported correlations between auditory SLMP and increased IFG activity in the left hemisphere contributed to various proposals about the role of mental imagery in neurocognitive functions. This included suggestions that auditory-verbal imagery uses the same neuroanatomical regions as either sound-based articulatory representations (Sato et al. 2004) or attention processes (Rudner, Rönnberg, and Hugdahl, K 2005). Likewise, in articles within Set-H the correlation between auditory SLMP and increased IFG activity in the left hemisphere contributed to various proposals about the neurocognitive dysfunction involved in hallucinations. For example, the increase in left IFG

169 Note that here 'inner speech' is treated as distinct from mental imagery which is mentioned separately (and just in passing) (Vercammen et al. 2011, 1009).

activity during AVH was taken to suggest that the ordinary language processing reinforce the pathophysiology of hallucinations (Ralph E. Hoffman et al. 2007). In addition, although the IFG was not the brain region of principal interest to their study, Diederen et al. (2010) reported an increase in this region in support for the claim that language-related regions of the brain are implicated in the dysfunctional neurocognitive mechanisms underlying hallucinations. Finally, for Vercammen et al. (2011) the increased IFG activity during hallucinations was investigated relative to the degree of 'loudness' and 'reality' reported to characterise these experiences, the results of which contributed to the proposal that a multi-step mechanism might explain hallucinations. As part of this, the 'aberrant reactivation' of the IFG (and other regions in the inner-speech network) were proposed to account for the characteristic sensory qualities of hallucinations, while 'higher-order' processes were proposed for the misattribution of meaning ('reality') given to these anomalous sensory experiences (Vercammen et al. 2011, 1013).

This comparison demonstrates that the similarities between the SLMP-neuroanatomical-correlates reported in experiments that used the concepts of either mental imagery or hallucination extended beyond the modality-specific sensory-processing regions. However, far from acknowledging these similarities, the pattern of knowledge-claims from the articles from Set-M and Set-H drew on these similar SLMP-neuroanatomical-correlates to generate disconnected knowledge proposals. For instance, similarities between the reported neuroanatomical correlates for auditory SLMP contributed to diverging knowledge-claims about the language-processing mechanisms that might underlie these phenomena. Once again, similar SLMP-neuroanatomical-correlates (increased IFG activity correlating to experiences of SLMP) were reported regardless of whether the SLMP investigated were conceptualised as mental imagery or hallucinations. At the same time, these similar experimental findings contributed to disconnected types of knowledge-claims (about functional or dysfunctional neurocognition) depending on the concept used for investigating SLMP (mental imagery or hallucinations)

6.1.3 Inferior Parietal Lobe

The Inferior Parietal Lobe (IPL) is another brain region within which SLMP-neuroanatomical-correlates are localised by fMRI techniques in experiments that documented the use of either the concept of mental imagery (twelve articles in Set-M) or hallucinations (eight articles in Set-H).[170] For example, increases in activity within the anterior IPL (supramarginal gyrus) were reported to correlate with experiences of both mental imagery and hallucinations.

This trend was consistent for investigations into both auditory and visual SLMP. In each case, these increases in IPL activity were of interest primarily because they were greater than the increases in IPL activity measured for a range of contrasting conditions/groups. Once again, activity within the ROI was reported in a range of ways within both sets. In set-M: activity in the anterior IPL was reported as greater during the manipulation of auditory-verbal mental imagery than during the mere generation of such images (Rudner, Rönnberg, and Hugdahl, K 2005); as greater during a visual mental imagery task in a group of neurotypical subjects and greater during a non-imagery task in a group of subjects diagnosed with autism (Kana et al. 2006); and as greater during a visual mental imagery task than a non-task baseline (Kaas et al. 2010, 802). In Set-H: activity within the anterior IPL was reported as greater for patients with visual hallucinations than matched patients without hallucinations (Stebbins et al. 2004); as greater for patients with higher-ratings in scales of hallucinatory severity and pathology (Koeda et al. 2013); and as greater during experiences of AVH than non-hallucinatory periods (Ralph E. Hoffman et al. 2007).

[170] The neuroanatomical bounds of the IPL *(inferior parietal lobe/lobule)* region are detatiled in Appendix 1 (Annotated Glossary); also see Set 2: ROI Analysis in Appendix 2.

However, despite diverse experiences of SLMP correlating to similarly localised changes in neural activity within the anterior IPL, comparing the articles from Set-M and Set-H once again illustrates how similar experimental findings routinely contributed to disconnected knowledge-claims. Firstly, in the articles from Set-M the findings (of increased activity within the anterior IPL) were taken in multiple ways: as suggesting that the manipulation of auditory imagery engages "largely non-phonological and possibly visuo-spatial mechanisms" (Rudner, Rönnberg, and Hugdahl, K 2005, 86); as suggesting that, in contrast to the expected use of imagery or linguistic strategies to comprehend different sentences, people diagnosed with autism "might routinely recruit visual imagery for comprehending [all] sentences" (Kana et al. 2006, 2491); and as evidence that non-memory dependent visual imagery relies on top-down influences originating in the parietal cortex (Kaas et al. 2010, 802). While differing, correlations between SLMP and increases in IPL activity within Set-M were typically taken as indicating the involvement of mental imagery in cognitive functions (such as visuo-spatial mechanisms or language processing).

Once again, knowledge-claims proposed in Set-M contrast with those made by articles in Set-H where similar correlations between changes in IPL activity and SLMP were reported. For example, within Set-H the findings of increased activity within the anterior IPL contributed to knowledge-claims about the dysfunction of neural activity in this area: with increased activity in IPL reported as "…suggest[ing] an alteration in functional brain relations [regulating sensory perception] that could predispose individuals to hallucinations"(Stebbins et al. 2004); as potentially "…play[ing] a direct role in generating or expressing AVHs" (Ralph E. Hoffman et al. 2007, 2794); and as "suggesting a dysfunction in [the IPL when] assessing auditory attractiveness" in schizophrenic patients (Koeda et al. 2013, 12). Even allowing for their differences, these claims all focused on the role of IPL activity in explaining hallucinations as a dysfunction in judging and/or regulating the neurocognitive processes involved in perception.

As the earlier examples demonstrated, an increase in activity within the IPL was reported to correlate with an experience of SLMP in articles from both Set-M and Set-H. This similarity contrasts with the disconnected knowledge-claims just outlined. These examples further demonstrate that diverging knowledge-claims can be generated from similar SLMP-neuroanatomical-correlates depending on how these phenomena are conceptualised.

In addition to this main trend, an additional pattern was also highlighted by the interest within both sets in the relevance of IPL connectivity for explaining experiences of SLMP. This interest in the connectivity of the IPL was most common in relation to its role within the Default Mode Network (DMN).[171] This included four articles from Set-M (Butler et al. 2006; Kana et al. 2006; Just et al. 2004; Weiler, Suchan, and Daum 2010) and three articles from Set-H (Ralph E. Hoffman et al. 2007; Sommer et al. 2012; Yao et al. 2014). One of these articles reported that the aim of their experiment was to investigate how visual mental imagery and inner language modulate resting state neural activity (Doucet et al. 2012). In relation to this aim, Doucet et al. (2012) reported a correlation between decreased functional connectivity within the DMN during both visual mental imagery and language-based thoughts. That there was no significant difference in IPL connectivity between imagery-based thoughts and language-based thoughts, was reported as a surprising result. Even so, this surprise finding was interpreted as indicative of "the unconstrained and unsupervised nature of thoughts driven by free association" (Doucet et al. 2012, 3199). In contrast, Yao et al. (2014, 5659) reported the IPL region as of interest due to various theories of hallucinations that attribute these SLMP to a dysfunction in the DMN that leads to abnormal connectivity

[171] For a discussion of the various roles of the IPL within the DMN, see (Broyd et al. 2009).

in top-down regulatory or self-monitoring processes. Despite this interest, Yao et al. (2014) did not report a significant difference in IPL connectivity when comparing subjects with visual hallucinations to those subjects without hallucinations. Nonetheless, the dysconnectivity hypothesis of hallucinations tested by Yao et al. (2014) was still supported by the reported experimental results due other regions within the DMN.

In both Doucet et al (2012) and Yao et al. (2014) expectations that experiences of SLMP can be understood in relation to connectivity of the IPL were not supported by the experimental results. However, each experiment was reported as offering different approaches to accommodating these surprising results. In each case, the response reflected to the different aims of investigating the DMN. I will return to these aims later. For now, the point is that even with unexpected results, similarly reported SLMP-neuroanatomical-correlates (this time within the IPL) contributed to diverging types of knowledge-claims (about functional or dysfunctional neurocognition) depending on how the SLMP investigated was conceptualised (as mental imagery or hallucinations).

6.1.4 Middle Frontal Gyrus

The Middle Frontal Gyrus (MFG) was the fourth most common ROI within which SLMP-neuroanatomical-correlates were reported regardless of whether the fMRI experiments documented investigating mental imagery (thirteen articles in Set-M) or hallucinations (ten articles in Set-H).[172] While not as frequently investigated as those ROI already discussed, SLMP-neuroanatomical-correlates were reported within the MFG region in more than a third of the documents from both Set-M (56%) and Set-H (37%). As with the other ROI, this included reported correlations between changes in localised activity and/or connectivity and the state and/or trait of experiencing SLMP (in both the auditory and/or visual modality)

[172] The neuroanatomical bounds of the *MFG (middle frontal gyrus)* region are detatiled in Appendix 1 (Annotated Glossary); also see Set 2: ROI Analysis in Appendix 2.

in a range of subject groups. Once again, even after accounting for these variables, increases in MFG activity were still reported to correlate with experiences of both auditory and visual SLMP in both sets.

In the case of auditory SLMP, greater increases in activity were reported in the anterior MFG during the state of experiencing both auditory imagery and auditory hallucinations. In Set-M, this included reports of bilateral increases in MFG activity during auditory-verbal imagery (Sato et al. 2004); an increase in the left MFG during auditory-verbal imagery (Rudner, Rönnberg, and Hugdahl, K 2005); and increases in the left MFG activity during auditory imagery more generally (Zvyagintsev et al. 2013). Meanwhile, in Set-H, the reports were of bilateral increases in anterior MFG activity during AVH (Kelly M.J. Diederen et al. 2010; Ralph E. Hoffman et al. 2007).

Once again, although these reported correlations between increased MFG activity and experiences of auditory SLMP were consistent across all articles, they contributed to disconnected knowledge-claims depending on whether the SLMP were conceptualised as mental imagery or hallucinations. For those articles in Set-M, reports of an increase in MFG activity during experiences of auditory imagery contributed to knowledge-claims about functional cognition. For example, a correlation between relative increases in MFG activity and auditory mental imagery supported proposals about the relationship between perception and imagery. This included proposals that the neural activation underlying experiences of auditory mental imagery overlaps with those underlying perception (Sato et al. 2004; Zvyagintsev et al. 2013). It also included proposals that supra-modal networks of activation underlie different modalities of mental imagery (Rudner, Rönnberg, and Hugdahl, K 2005; Zvyagintsev et al. 2013). Within Set-H, the reported correlations between experiences of auditory hallucinations and increased MFG activity were either not considered significant compared to other experimental results (Ralph E. Hoffman et al. 2007) or of interest only in relation to a comparison between patients who hallucinate and healthy control subjects (Kelly M.J. Diederen et al. 2010). Given this, reported correlations between increased MFG activity and the state of experiencing hallucinations were overshadowed by interest in the results from regions more relevant to the proposed role of ordinary language processing (Ralph E. Hoffman et al. 2007) or memory (Kelly M.J. Diederen et al. 2010) in the mechanisms underlying hallucination pathology.

As this comparison illustrates, reported correlations between auditory SLMP and increases in MFG activity contributed to a range of disconnected knowledge-claims (when considered relevant at all). This comparison also demonstrates that these proposals diverge to contribute to knowledge-claims about the neurophysiological mechanisms that underlie either the ordinary functions that involve mental imagery or the pathological dysfunction responsible for hallucinations.

The divergence from similar reports of SLMP-neuroanatomical-correlates to disconnected knowledge-claims was also evident in a comparison of studies within the MFG subset that investigated visual SLMP. Firstly, there were the expected similarities in the changes in MFG activity reported to correlate with visual SLMP in experiments documented by articles from both Set-M and Set-H. In particular, an increase in MFG activity was repeatedly correlated with the state of experiencing visual mental imagery in Set-M (Butler et al. 2006; de Borst et al. 2012; Ganis, Thompson, and Kosslyn 2004; Kana et al. 2006; Mechelli et al. 2004; Weiler, Suchan, and Daum 2010; Zvyagintsev et al. 2013). This included reports of specific activity within the posterior MFG bilaterally (Butler et al. 2006); the left posterior and anterior MFG (Zvyagintsev et al. 2013); and the BA9, in the middle part of the MFG, bilaterally (Slotnick, Thompson, and Kosslyn 2012). Likewise, an increase in MFG activity was repeatedly correlated with the state of experiencing visual hallucinations in Set-H (Goetz et al. 2014; Shine, Halliday, et al. 2014; Yao et al. 2014; Ramírez-Ruiz et al. 2008). As with

Set-M, this included reports of specific activity within the left posterior MFG (Ramírez-Ruiz et al. 2008); the posterior MDF bilaterally (Shine, Halliday, et al. 2014), and the BA9, in the middle part of the MFG, bilaterally (Yao et al. 2014).

Secondly, reported correlations between increased MFG activity and visual SLMP contributed to a range of proposals that – when comparing those articles from Set-M and Set-H – diverge from the similarity of the reported experimental findings to generate disconnected knowledge-claims. In Set-M, when increased activity in the MFG correlated with experiences of SLMP it contributed to a range of potentially conflicting proposals about neurocognitive function. For example, correlations between increased activity in the MFG and experiences of visual SLMP contributed to the proposal that, "when appropriately matched, visual perception and visual mental imagery activate the same subset of prefrontal regions" (Ganis, Thompson, and Kosslyn 2004, 237); as well as in support of the proposal that – in contrast to bottom-up perceptual processes, context-specific imagery is mediated by top-down mechanisms (Mechelli et al. 2004, 1264). At the same time, other articles within Set-M reported increases in MFG activity during visual imagery as interesting only in comparison to similarly localised increases in other conditions/groups. For example, an increase in MFG activity was considered of interest in comparison to the greater increase in the posterior MFG activity reported for experiences of either auditory mental imagery (Zvyagintsev et al. 2013), or abnormal visual imagery (Kana et al. 2006). Investigated in these ways, increases in MFG activity during visual imagery contributed to proposals that the MFG is involved in the modality-specific network underlying visual imagery (Zvyagintsev et al. 2013, 1431); and in the process of "transforming sentence information into a visual image" (Kana et al. 2006, 2488).

In contrast to Set-M, correlations between experiences of visual SLMP and increased activity in the MFG were only ever of interest in Set-H when they were reported to be less of an increase than similarly localised activity in the other experimental groups. Investigated in this way, increases in posterior MFG activity reported to correlate with experiences of visual hallucinations were emphasised as being lesser increases than those correlated with non-hallucinatory experiences (Goetz et al. 2014; Ramírez-Ruiz et al. 2008; Shine, Halliday, et al. 2014). As such, the knowledge-claims that these findings contributed included proposals that "aberrant 'top-down' processing of the visual system gives rise [to hallucinations]" (Goetz et al. 2014, 116); that "decreased activation in frontal network associated with attention could predispose to [hallucinations] due to an abnormal processing of visual stimuli" (Ramírez-Ruiz et al. 2008, 2339); and that patients with hallucinations are unable to recruit activation in the dorsal attention network (Shine, Halliday, et al. 2014, 2218).

As this comparison demonstrates, when correlations between increases in MFG activity and visual SLMP were reported as relatively small compared to other experimental conditions, they contributed to knowledge-claims that differed depending on how the SLMP were conceptualised. The pattern of these differences is similar to the contrasting pattern between the knowledge-claims generated from the correlation between increases in MFG activity and auditory SLMP by articles in Set-M and Set-H. Firstly, as expected, in both cases increases in MFG activity during these SLMP were documented across both Set-M and Set-H. Secondly, a comparison of the relevant articles in each case illustrates that similar correlations (between increased MFG activity and experiences of SLMP) are reported by fMRI experiments that use different concepts in the process of generating diverging knowledge-claims. In the case of articles from Set-M, investigating auditory and/or visual SLMP, these knowledge-claims centred on the similarities and differences between imagery and perception, or on the role of imagery in language processing. Whereas, articles in Set-H tended to treat correlations between increases in MFG activity and auditory SLMP as supplementary findings; focusing instead on other findings (that more directly supported explanations of hallucinations in terms of a disruption of either language or memory processes). As an overview, when knowledge-claims were generated from findings of MFG activity within Set-H, the focus was on the possibility that visual perception processes are inappropriately attended to or inadequately regulated lead to hallucinations.

Therefore, as in the other ROI discussed, knowledge-claims focused on the role of the MFG region in cognitive function in those articles within Set-M, while, when similar MFG activity was documented by articles in Set-H, it provided evidence for knowledge-claims about dysfunctional neurocognitive processes. This analysis of the MFG ROI-subset of articles therefore converges with those outlined above for the STG, IFG, and IPL regions. In brief, for each of the ROI-subsets considered, I have concentrated on demonstrating that the reports of similar SLMP-neuroanatomical-correlates in the articles in Set-M and Set-H contributed to the differences in the types of knowledge-claims proposed within each set of articles. In this way, the examples from these four ROI-subsets have provided repeated instances of similar SLMP-neuroanatomical-correlates being reported in experiments that use the concepts of either mental imagery or hallucinations.

Furthermore, for each of the experiments that reported these similar experimental findings, diverging knowledge-claims were generated about the mechanisms underlying SLMP experiences. In particular, the preceding analysis of these overlapping ROI-subsets of articles demonstrates that – regardless of the ROI in question – experimental findings of SLMP-neuroanatomical-correlates contributed to knowledge-claims about cognitive function when the fMRI experiment used the concept of mental imagery, while similar SLMP-neuroanatomical-correlates provided evidence for knowledge-claims about the dysfunctional neurocognitive processes when the experiment uses the concept of hallucinations.

6.2 Examining Concept-Use to Help Explain Diverging Knowledge-claims

The ROI-subsets examined above each offer paradigmatic examples of equivalently localised changes in neural activity that have been reported to correlate with SLMP experiences conceptualised as both mental imagery and hallucinations (in separate experiments). In addition, my analyses indicate that these experiments generated a range of disconnected knowledge-claims based on reports of these similar SLMP-neuroanatomical-correlates. Furthermore, comparing the articles in Set-M and Set-H highlights that the types of knowledge-claims differed in terms of the discrete explanations proposed to explain either the role of mental imagery in neurocognition or the dysfunctional neurocognitive processes responsible for hallucinations.

To examine this divergence, the correlations between SLMP experiences and each of the ROI discussed above can be reviewed in relation to the diverse types of knowledge-claims these correlations generated. However, given the intersecting trends relating to those knowledge-claims featuring the role of SLMP in memory, attention, and language processes, I will assemble the following discussion by comparing the relationship between SLMP and perceptual processes depicted in these various proposals.

The first thing to note was the relationship between SLMP and perception in those experiments investigating the possibility that mental images share resources with perceptual processes compared to those experiments seeking to determine whether hallucinatory experiences disrupt perceptual processes. In both of these types of investigations, brain areas previously established as being involved in perceptual processes (for the relevant modality of SLMP) were, unsurprisingly, of particular interest.[173] Given this, articles that investigated

[173] Given that the ROI considered above include the auditory-processing areas (within the STG) but not the visual-processing areas (within the occipital lobe) the examples chosen all relate primarily to the auditory modality. However, it is worth noting that while articles within Set-M commonly investigated the perceptual similarity of visual imagery, investigations into visual

the STG region – which is considered critical to processing auditory stimuli (Anthoney 1994, 587; Bowden 2015; Duvernoy 1991, 7, 10) – provide examples of this initial difference between experimental approaches to the relationship between SLMP and perception.

Starting with Set-M, Halpern et al. (2004, 1288) reported that increased activity in the STG accompanies both the perception and imagery of comparing the timbre of different auditory stimuli.[174] For Halpern et al. (2004, 1288), this finding helped to "confirm that people can compare imagined timbers in a similar way as they do perceived timbers". Also focusing on a modality-specific investigation of mental imagery, Bunzeck et al. (2005, 1120) documented an experiment that sought to determine "which subdivision of the auditory cortex is involved in [complex sound] imagery". In relation to this aim, Bunzeck et al. (2005, 1125) reported that STG activity increased within the auditory association areas but not the primary auditory areas during imagery of complex sounds. Combining this finding with their other results, this experiment was reported to contribute to "evidence that perception and mental imagery of complex sounds rely on overlapping but dissociable neural correlates" (Bunzeck et al. 2005, 1125).

In both these examples from Set-M, the STG region was investigated in relation to whether the mechanism underlying auditory images overlap with those responsible for auditory perception. In the earlier study, the overlapping SLMP-neuroanatomical-correlates reported for both imagery and perception were of interest because of the sensory-like characteristics of mental imagery. Indeed, Halpern et al. (2004, 1281) opened their introduction with a description of musical imagery as "so vivid and durable that songs get

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hallucinations were more likely to focus on the possibility that disrupted attentional processes underlie these phenomena.

174 As part of this, Halpern et al. (2004, 1285) argued that using visual imagery as a control condition for investigating auditory imagery was superior to using a silent baseline given that wide-spread increases in sensory-area activity were found for each of the three test conditions (perception, auditory imagery, and visual imagery) when compared to a silent baseline.

'stuck' in the head". Whereas, building on prior research into this overlap, Bunzeck et al. (2005, 1125) do not even describe auditory imagery. Nonetheless, seeking to examine whether these sensory-qualities arise through the activity of regions associated with perceptual processes, both approaches expected that there would be greater activation in these areas during perception than during imagery (Bunzeck et al. 2005, 1120; Halpern et al. 2004, 1290).

Recalling the historical context for the current uses of the concept of mental imagery (from Chapter Four) this expectation can be understood in relation to the implicit characterisation of imagery as an experience easily delineated from perception. This entrenched expectation was especially evident when overlaps between the neural correlates of SLMP and perception were reported in Set-M. In this context, these results were considered more relevant to isolating modality specific processes potentially involved in imagery than to understanding the perceptual-similarity of these experiences. This can be seen in Bunzeck et al. (2005, 1125) when they speculated that "the bottom-up analysis of sensory input requires more neural resources… than the reactivation of the same stimulus during mental imagery". Likewise, a similar expectation is revealed by Halpern et al.'s (2004, 1290) explanation that any activity in auditory-processing regions during an internal representation of sound was 'notable', while a difference between STG activity in the perception and imagery conditions was "consistent with the phenomenological and empirical differences between perception and imagery".

These entrenched associations can also be seen in articles within Set-M that implicated the STG region in proposals about the role of imagery in language processes. For example, an increase in STG activity during a task considered to require auditory-visual imagery was reported, by Sato et al. (2004, 1149), as consistent with other studies that have implicated the STG in auditory imagery and verbal monitoring tasks. Complementing this, Rudner et al.

(2005, 87) reported that both the generation and manipulation of auditory-verbal imagery "activated similar neural regions in the left anterior superior temporal lobe…. [an area associated with] a functional specialisation for the perception of intelligible speech". Meanwhile, Just et al. (2004) documented two experiments that investigated the role of multi-modal imagery in language processing. In introducing these experiments, Just et al. (2004, 112) commented that "Understanding a text on architecture or automobile design seems impossible without mental imagery". Within this context, when STG activity during the comprehension of these types of high-imagery sentences was found to be lower than the activity measured during the parsing of low-imagery sentences, Just et al. (2004, 117) drew on previous proposals that this region is required for the semantic processing of abstract concepts required in the absence of high-imagery content. At the same time, increases in frontal and parietal areas during comprehension of this type of 'high-imagery' text were suggested to "play a role in generating internal representations (perhaps including articulatory attributes) that are used in [the] maintenance and communication [involved in the] working memory function that is used in sentence comprehension" (Just et al. 2004, 117).

Clearly, investigations into the role of the STG region in SLMP within Set-M were framed by an expected relationship between auditory imagery and both perceptual and language processes. In contrast, interest in the STG region within Set-H centred on investigating how hallucinatory experiences disrupt ordinary perceptual and language processes. For example, Ford et al. (2009, 59) reported that they focused their analysis on the auditory areas within the STG and MTG "to test the theory that voices would compete with external sounds for auditory processing resources". The possibility that perception and hallucinations compete for resources was also mentioned by studies investigating whether voice-recognition areas are implicated in AVHs (Zhang, Hao, et al. 2008); whether there are hemispheric differences related to voice perception in patients with schizophrenia (Zhang, Shi, et al. 2008); and whether the degree of activity in language and memory areas correlate with the level of hallucinatory experience (Wible et al. 2009). In each case, when a correlation was reported between increased STG activity and AVHs, it typically contributed to proposals that dysfunction within the auditory perception of speech contributes to the abnormal language-processes that produce hallucinations (Ford et al. 2009; Wible et al. 2009; Zhang, Hao, et al. 2008; Zhang, Shi, et al. 2008).

These examples from Set-H suggest that experimental findings were framed by the expectation that hallucinatory experiences interfere with auditory perception and/or language processing in some way. This expectation is also evident in the use of a task requiring the assessment of auditory-perception (specifically, of distinguishing between hearing one's own voice and hearing another person's voice) in Mechelli et al.'s (2007, 1217) investigation of the role of STG connectivity in AVHs. This expectation is even more explicit in an experiment, documented by Vercammen et al. (2011), intended to test the misattribution of inner-speech hypothesis of AVHs. As part of this, and despite criticising the inner-speech hypothesis, Vercammen et al. (2011, 1013) supported the possibility that "as AVHs become more perceptually salient (i.e. louder), they take up more resources involved in the processing of inner speech".

Alongside this explicit interest in direct relationships between SLMP and perception, other experiments focused on investigating whether there were additional mechanisms involved in regulating these relationships. Contributing to this line of enquiry, there were two distinct approaches: investigations into how top-down mechanisms regulate the recall, inspection, and judgement of mental imagery, or investigations into whether the dysfunction of these regulatory mechanisms might explain hallucinations. These investigations into the relationship between SLMP and the regulation of sensory experiences (perceived or imagined) frequently reported correlations between experiences of SLMP and activity within the IPL, IFG, and MFG regions. Interest in these regions in relation to regulatory processes is consistent with the overlapping range of top-down functions associated with these three areas – including executive control of behaviour, language, memory, and attentional processes (Bernal and Perdomo 2008).

Starting with Set-M again, the MFG region was implicated in the cognitive control processes proposed to function similarly in both visual imagery and visual perception (Ganis, Thompson, and Kosslyn 2004). Complementing this, Mechelli et al. (2004) proposed that this region contributes to the content-sensitive top-down mechanisms proposed to regulate imagery experiences (based on a finding that relative increases in MFG activity correlate with content-specific visual images). Focusing instead on identifying the neuroanatomical correlates for experiences of manipulating auditory-verbal imagery, Sato et al. (2004, 1144) designed a task intended to require subjects to recall, manipulate, and monitor, mental representations of speech forms. Interpreting the results of this experiment, Sato et al. (2004, 1148–49) reported that the IFG was involved in the use of imagery in the "on-line analysis of articulatory speech forms that support communicative or interpretative speech".

Combined with their other results, this interpretation contributed to the proposal that the manipulation of auditory-verbal imagery "shares common components of speech perception and speech production" (Sato et al. 2004, 1149). Taking a similar view of visual imagery supporting recall memory, Wais et al. (2010, 8541) hypothesised that visual memory might be using the same attentional resources as visual perception. Based on their findings, Wais et al. (2010) proposed that memory performances rely on visual imagery and so could be impaired by distractions in the visual perceptual field. More recently, both the MFG and the IFG regions were implicated in the top-down regulation proposed to explain the competition between different imagery modalities within the supra-modal network proposed to underlie both auditory and visual imagery (Zvyagintsev et al. 2013, 1413).

Turning again to Set-H, correlations between IFG activity during hallucinations and the subject's score on the SRH scale were reported to "converge with the theoretical literature… and recent imaging findings… to suggest that the IFG correlates of the SRH [subjective reality of hallucinations] comprise the perceptual key substrate for AVHs" (Raij et al. 2009, 2999). A finding in a later study, of connectivity between the right IFG and the left IPL was lower in schizophrenic patients with hallucinations (than comparable patients without hallucinations), was taken to "suggest a relative dysfunctional interaction between language production areas of the right hemisphere and speech perception regions of the left hemisphere" (Vercammen et al. 2010, 914–15).

Elsewhere, following a study on hallucinations in patients with epilepsy, Korsnes et al. (2010, 616) compared their results with a selection of prior studies on patients with schizophrenia to suggest that mechanisms underlying auditory hallucinations – including lower activity in the IFG and STG regions during listening tasks in the patient-group than in the control-group – are independent of diagnostic categories. In addition, relatively low increases in MFG during visual hallucinations were reported in a way that contributed to the knowledge-claims that 'aberrant' top-down mechanisms contribute to this symptom of Parkinson's disease (Goetz et al. 2014). Elsewhere, relative increases in IPL activity contributed to knowledge-claims that AVHs may involve the dysfunctional assessment of auditory stimuli (Koeda et al. 2013, 12), and that the alterations in the functional relations regulating sensory perception could predispose individuals to experiencing visual hallucinations (Stebbins et al. 2004).

In brief, it is dysfunctional perceptual processes (whether directly or as a failure to regulate the role of these processes in the service of language and memory) that featured in these explanations of the pathological 'sense of reality' during hallucinations. This was the case even when this sense of reality was attributed to the typical hallucinatory characteristic of a high degree of perceptual similarity. In this way, the entrenched associations inherited from the inverse characterisation of hallucinations with those of mental imagery continue even as the concepts are used independently of each other.

Despite these independent uses, the examples in this section highlight that the characterisations of mental imagery and hallucinations each continue to reflect their interdependent histories. This supports my suggestion from Chapter Four that the inverse characterisation between mental imagery and hallucinations persist despite mental imagery being down-graded to merely one of the ordinary process thought to be disrupted by hallucinations. In continuing to rely on these inverse characteristics, the independent uses of these two concepts can be seen to draw on a shared set of entrenched associations about the role for SLMP in mediating between sensation and abstract thought.

In the examples from Set-M, these associations are evident in the attempts to identify mechanisms underlying those SLMP with ordinary perceptual similarity and/or the regulatory processes expected to be critical to the function of mental imagery. Likewise, in the examples from Set-H, the same associations are evident in attempts to explain the mechanisms underlying SLMP with abnormal perceptual similarity and/or the regulatory processes expected to be disrupted in hallucinatory experiences. In each case, characteristics such as the degree of volitional control and/or sense of reality implicitly draw on the series of associations within which there is a need to carefully regulate ordinary SLMP.

In the earlier section, similar SLMP-neuroanatomical-correlates were seen to generate different knowledge-claims about the relationship between SLMP and perceptual processes. In some ways, this divergence can be seen to relate to the delicate 'framing' of the human-material interactions of experimental practice in ways that align with specific conceptual structures. As discussed in Chapter Two, Pickering (2006a, 278) suggests that this process of framing allows the material agency captured by machines to pass through the levels of abstraction and conceptual multiplicity required to generate theoretical and factual knowledge.

This alignment process can be further illustrated in those cases where, when similar SLMP-neuroanatomical-correlates were reported from experiments using both mental imagery and hallucinations, the SLMP-neuroanatomical-correlates in question was ignored in favour of other experimental results. For example, results relevant to the potential modality-specific mechanisms for SLMP were often overshadowed by other findings; specifically, those findings considered more relevant to either memory (in the case of STG results reported in experiments investigating visual mental imagery) or both language and memory (in the case of the MFG results reported in experiments investigating auditory hallucinations).

This chapter started with the observation that similar changes in neural activity within each of the ROI examined were reported to correlate with SLMP experiences conceptualised as either mental imagery or hallucinations. Based on this observation, I have detailed my analyses of articles grouped by the ROI implicated in the knowledge-claims proposed in relation to explanations about the mechanisms underlying either mental imagery or hallucinations. This examination focused on the reported correlations between each of these ROI and either mental imagery or hallucinations. In doing so, it highlights two distinct patterns in the knowledge-claims similar experimental findings generated. Firstly, the proposed knowledge-claims diverged from similar experimental findings to support disconnected explanations for how SLMP either rely on or disrupt ordinary perceptual processes. Secondly, the functional/dysfunctional role attributed to SLMP consistently aligned with the concept used in the design of the experiment was mental imagery or hallucinations respectively.

Viewing these two patterns together suggests that disconnected knowledge-claims were generated depending on whether a given SLMP-neuroanatomical-correlate was identified using the concept of mental imagery or hallucinations. One explanation for this divergence could be the largely independent uses of the concepts of mental imagery and hallucinations (detailed in Chapter Three). However, the pattern of diverging knowledge claims from similar experimental finings held even in those few cases where the articles mentioned the concepts of both mental imagery and hallucinations. Furthermore, the independent uses of these two concepts (mental imagery and hallucinations) does not explain why this divergence occurs across reported experiments that rely on shared techniques and disciplinary contexts, as well as those that differ in these regards.

As discussed in Chapters One and Two, there are a range of heterogeneous components within the dynamics of experiments that contribute to the knowledge that these practices generate. Given the focus on concept-use, I have not yet examined these other contributions in any depth. However, the examination so far does suggest that the divergence of knowledge-claims from similar experimental findings occurred independently of a range of other key components of these experimental practices. This can be demonstrated by considering some potential objections to my focus on the structured uses of conceptual tools in neuroimaging experiments.

The most obvious objection to my focus on conceptual tools might be that the differences between Set-M and Set-H reflect differences in technical practices between Set-M and Set-H. However, as detailed in Chapter Five, the fMRI techniques documented within the two sets of articles share enough similarities that they can be considered comparable. Furthermore, as demonstrated in the preceding analyses, the concept used in these experiments contributed in consistent ways that cut across a range of methodological and technical variables reported by both sets of articles. One aspect of the consistent ways in which each concept contributed to these experiments can be seen in the distinct types of knowledge-claims that were generated within the experiments reported by the articles in Set-M and Set-H. For example, when the concept used in the design of the experiment was mental imagery it consistently aligned with knowledge-claims that explained the underlying mechanisms of these SLMP experiences in terms of function. Conversely, when the concept used in the design of the experiment was hallucinations it consistently aligned with knowledge-claims that explained the underlying mechanisms of these SLMP experiences in terms of dysfunction.

Another potential objection to my analysis is that differences between Set-M and Set-H were due to a divide between psychological and psychiatric disciplines. However, a disciplinary explanation is inadequate given that the tangled-yet-independent uses of the concepts of mental imagery and hallucinations were not limited to distinct disciplinary contexts. Instead, regardless of the concept used in each experiment, these experiments were reported by authors affiliated with psychology departments, psychiatry departments, variously defined neuroscience departments, and/or by authors representing interdisciplinary collaborations across departmental and institutional boundaries. Even when considering only the lead authors, the uses of the concepts of mental imagery and hallucinations were still not divided by disciplinary borders. For example, even when the same author was involved in investigating SLMP conceptualised as both mental imagery (in one experiment) and hallucinations (in another experiment) the independent uses of these concepts was maintained. For example, Andrea Mechelli was involved in an experiment investigating the mechanisms that mediate content-specific perception and/or imagery in the visual modality, as well as in a later experiment that investigated the mechanisms involved in the dysfunctional mediation of speech perception in AVH (Mechelli et al. 2004, 2007).[175]

A third potential objection is that the differences between Set-M and Set-H were due to differences in the focus of the specific journals that these neuroimaging experiments were reported within. This possibility is also of minimal concern: articles that used the concepts of either mental imagery or hallucinations were published in a range of overlapping journals that could not be delineated based on their expectations for research to focus on either function or dysfunction. Indeed, five journals were represented in both Set-M and Set-H (albeit unevenly). This overlap can be understood in part because a third (33%) of the twenty-four journals represented across both sets focused on curating interdisciplinary research relevant to understanding both functional and dysfunctional neurocognitive processes. For example, the mission statement for the *Frontiers in Human Neuroscience* journal begins by stating a devotion to "understanding the brain mechanisms supporting cognitive and social behaviour in humans, and how these mechanisms might be altered in disease states" (Nagarajan and Heekeren 2015). In addition to this, the concept of hallucinations was also used in articles published in journals that had a focus on functional neurocognitive processes. For example, Hoffman et al. (2007) published an investigation of the pathophysiology of hallucinations in *Cerebral Cortex* – a journal that focuses on publishing multidisciplinary research "on the development, organization, plasticity, and function of the cerebral cortex" ('Cerebral Cortex | Oxford Academic' 2017).[176]

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175 Despite the shared author, the later article did not cite their earlier one. Furthermore, while the earlier study was cited numerous times within Set-M and the later study was cited numerous times within Set-H, neither was cited at all by any articles in the contrasting set.

176 Also see the article by van de Ven's et al. (2005) published in a journal that focuses on the "study structure-function and brain-behavior relationship" ('NeuroImage' 2017).

This overlapping publication context is also evident in the citation patterns within the articles analysed. Indeed, while there was no direct cross-citation between the articles analysed, there was a small selection of research that was cited by articles in both Set-M and Set-H. For example, a proposal that hallucinations involve dysfunctional self-monitoring of auditory-verbal imagery (Sukhwinder S. Shergill et al. 2000) was cited by articles in both Set-M and Set-H; albeit for dramatically different purposes depending on the article-set. In Set-H, the Shergill et al. (2000) report was cited among prior studies supporting the proposed role of the STG region in AVHs without any reference to auditory-verbal imagery (Mechelli et al. 2007; Vercammen et al. 2011). Whereas, in Set-M, the Shergill et al. (2000) publication was referenced within a list of examples where auditory imagery was presented as playing a role in language tasks, music perception and cognition, and "even auditory hallucinations in schizophrenia" (Sato et al. 2004, 1143). This was only a passing reference, and the list of examples followed the statement that auditory imagery "plays an important role in numerous cognitive functions whenever auditory material is represented for analysis to make comparisons or to form interpretations from" (Sato et al. 2004, 1143).

In this way, even when resources that discuss the potential relationship between mental imagery and hallucinations were shared by articles from both Set-M and Set-H, the concepts were used independently of each other in ways that drew upon the mediator-view series of associations. I will come back to these associations when I explore their role in structuring the uses of each concept in later chapters. For now, that various resources cross the semi-permeable boundaries between the diverse disciplines involved in investigating the SLMP-neuroanatomical-correlates accentuates the limitations of explaining difference between Set-M and Set-H by either a disciplinary divide or publication expectations.

In addition, the divergence cannot be attributed to differences between Set-M and Set-H on theoretical or technical considerations. Across each of these variables, experiments that investigated the SLMP-neuroanatomical-correlates using the concept of either mental imagery or hallucinations routinely did so without explicating how the SLMP of interest is delineated from other types of SLMP. Furthermore, as the earlier examples illustrate, the knowledge-claims generated by these experiments typically focused on the possibility that unique mechanisms might underlie the conceptualisation of the types of SLMP investigated (rather than on the possibility that overlapping processes might diverge elsewhere to become discrete forms of SLMP). This suggests that similar experimental findings helped to generate disconnected knowledge-claims that diverged to contribute to distinct epistemic goals within the overlapping research communities.

Within an understanding of concepts as used for investigating specific epistemic goals, these examples highlight how diverging knowledge claims can hinge on whether the experiment was designed with a conceptualisation of the SLMP as either mental imagery or hallucinations. It further suggests that these diverging contributions reflect more than a role in differing interpretations of experimental results in ways that align with specific epistemic goals. Indeed, the concepts of mental imagery and hallucinations appear to actively contribute to the very experimental practices that generate the unit contributions to scientific knowledge these articles propose. This further possibility will be explored in more detail in Chapter Seven. For now, my analyses so far support an initial conclusion – that, in each shared ROI-subset reported across multiple disciplines and a range of methodological techniques, the type of knowledge-claim depended on whether the SLMP investigated in the experiment was conceptualised as mental imagery or as hallucinations.

Positioned within the broader context of this thesis, the implications of this conclusion are that these diverging knowledge-claims hinged on a key variable within the heterogeneous interactions contributing to these experiments: the conceptualisation of the type of SLMP experience being investigated. Knowledge-claims generated based on SLMP-neuroanatomical-correlates may therefore depend on presuppositions carried-along by the conceptualisation used to individuate the SLMP experiences in the first place. Given this, the interdependent histories of these two concepts provide an avenue for examining the role of these concepts in contributing to the generation of diverging knowledge-claims from similar experimental findings. As demonstrated in Chapters Three and Four, these interdependent histories reveal that the independent uses of these two concepts are each structured by a shared network of entrenched associations. Approached in this way, the divergence of knowledge-claims from similar experimental findings can be seen to extend beyond what might be expected given the difficulties of interpreting neuroimaging data and any broader disciplinary differences.

This possibility is consistent with the description of the active role for conceptual tools in experimental practices outlined in Chapter Two. Indeed, to repurpose Picking's terminology, the divergence indicates that the point at which the material agency captured by experimental techniques is framed (to align with conceptual structures) begins earlier than usually supposed: contributing to far more than simply the interpretation of experimental findings. Instead, this divergence might be better understood as due to the unintended contributions of these conceptual tools to the entirety of documented experimental practices: contributions that stem from the structured uses of the concepts of mental imagery and hallucinations as each was used to pursue discrete epistemic goals. Therefore, in Chapter Seven I will examine the role of these two concepts within earlier stages of the experimental practices, as documented within the articles in Set-M and Set-H.

7 Methodological Procedures and the Uses of Concepts

Structured uses of the concepts of mental imagery and hallucinations provide tools that actively contribute to experimentally generated knowledge about SLMP. In Chapter Six I focused on the role of these contributions in interpreting experimental results: examining how different fMRI experiments generated similar findings (equivalent SLMP-neuroanatomical-correlates) yet proposed diverging knowledge-claims. In this examination, I argued that the structured uses of the concept of mental imagery or hallucinations can be seen to contribute to generating knowledge-claims about either ordinary or pathological SLMP. In this chapter I focus on exploring how, in addition to their role in interpreting results, the structured uses of concepts can also contribute to the design and implementation of experimental methods.[177]

I will begin this comparison by examining how specific types of SLMP were individuated by the concept of mental imagery and hallucinations respectively. Following this, I will consider how experimental aims were articulated. Finally, I will discuss a selection of common types of experimental conditions used to isolate SLMP-neuroanatomical-correlates during fMRI scanning. In offering this comparison of the experimental procedures (as documented by articles in Set-M and Set-H), I aim to demonstrate that otherwise similar methodological steps differed in ways that aligned with the concept used for the type of SLMP being investigated. This comparison demonstrates how the structured uses of the concepts of mental imagery and hallucinations operated as tools during the design and implementation of neuroimaging experiments. My argument is that, when used in these ways, the concepts of mental imagery and hallucinations contributed to the methodological

[177] For a discussion of my method and related considerations see Chapter Five.

conditions for investigating SLMP in relation to either ordinary or dysfunctional neurocognitive processes.[178]

7.1 Individuating SLMP for Further Investigation

While not an explicit part of formally reported methods, individuating the phenomena investigated is an important step in experimental practice (as discussed in Chapter Two). In relation to this, I described earlier how the concepts of mental imagery and hallucinations are each used to individuate types of SLMP for the purposes of investigating different epistemic goals (in Chapters Three and Four). The stability of using each concept in these ways is further demonstrated by the descriptions offered for SLMP in the fMRI experiments documented in Set-M and Set-H. In line with this, the process of individuating a specific type of SLMP typically relied on the selection of subjects: healthy subjects were assumed to experience ordinary SLMP (mental imagery); meanwhile, any history of hallucinatory-like experiences was taken to indicate a predisposition to experience dysfunctional SLMP.[179] A minority of articles also provided an additional procedure for verifying that the SLMP of interest were experienced during the experimental conditions.

Considering SLMP descriptions, subject selection processes, and additional attempts to verify SLMP experiences in turn, this section will detail how the concepts of mental imagery and hallucinations were each used to individuate specific types of SLMP within the experimental practices documented in Set-M and Set-H respectively.

[178] In doing so, I will once again draw on various arguments presented earlier in this thesis; these connections will be clarified in more detail in the following chapter.

[179] Subject selection is an important aspect of research design that presents challenging methodologically issues within neuroimaging research specifically (Thirion et al. 2007, 117), as well as within research more generally (Reybold, Lammert, and Stribling 2013, 703).

7.1.1 Describing Sensory-like Mental Phenomena

In the articles examined, descriptions of SLMP were broadly consistent with the definition of either mental imagery or hallucinations. As detailed in Chapter Three, the definitions of both concepts describe specific types of SLMP: mental imagery resembles perception; whereas hallucinations have a compelling sense of perception. However, as argued earlier, there are many ambiguities that continue to present challenges to reliably differentiating between desirable and undesirable SLMP as distinct types of phenomena. As such, the uses of each concept rely on shared associations about the mediating role of SLMP; characterising ordinary and pathological SLMP as the inverse of the other. In Chapter Four I argued that these associations provide the structure within which the concepts of mental imagery and hallucinations are each implicitly delineated in relation to other, even while operating independently. Similarly, this interdependence between descriptions of mental imagery and hallucinations continues alongside their independent uses for investigating discrete experiences of ordinary and pathological SLMP. In highlighting this, I seek to demonstrate that entrenched mediator-view associations of SLMP are critical to the individuation of specific types of SLMP as either ordinary or pathological for investigation in fMRI experiments.

In the articles examined, descriptions of SLMP came in many forms: as explicit definitions; as introductory examples; and as passing references to a selection of characteristics considered typical of the SLMP being investigated. In each case, little information was provided about how the type of SLMP investigated were individuated from other types of SLMP. Instead, each concept was assumed to successfully individuate a discrete type of SLMP that could be investigated for a specific purpose. The concept of mental imagery was expected to individuate *ordinary* SLMP; the concept of hallucinations was expected to individuate *pathological* SLMP. These expectations (that each concept can reliably individuate the type of SLMP of interest) can be illustrated by comparing some examples from articles in Set-M and Set-H.

Firstly, a small number of articles provided explicit definitions for the concept used to investigate the SLMP of interest (either mental imagery or hallucinations). The most cursory of these definitions specified only the sensory-likeness of the mental phenomena of interest. As such, some definitions of mental imagery and hallucinations were remarkably similar. These offer little to clarify the type of SLMP under investigation. For example, Kaas et al. (2010, 794) define "Mental imagery [as] a perceptual experience occurring in the absence of appropriate external stimulation". With strikingly similar language, Ćurčić-Blake et al. (2013, 1087) reported that "Hallucinations have been defined as perceptual experiences in the absence of corresponding external stimuli".

While not always so striking, similarities within the definitions offered for mental imagery and hallucinations are common. For example, this reliance on the core sensory-likeness of SLMP in defining either mental imagery or hallucinations extends to modality-specific investigations. In line with the focus on visual modality within Set-M, Diekhof et al. (2011, 1704) reported that "Mental imagery or 'seeing with the mind's eye' holds the power to build up vivid internal 'as if' representations, which enable a mental simulation of actual visceral and emotional responses". Within Set-H the modality of principal interest was auditory SLMP. In line with this, Zhang et al. (2008, 477) reported that "Auditory verbal hallucinations (AVHs) refer to the experience of perceiving speech in the auditory modality without corresponding external stimuli".

When additional details were provided, definitions of each concept drew on the typical characteristics associated with the concept used. Once again, each concept was taken as reliably individuating a specific type of SLMP; with the typical characteristics presented without any explanation or justification. For example, the opening sentence of an article in

Set-M declared that "Auditory imagery can be defined as an introspective and conscious persistence of an auditory experience in the absence of related auditory input" (Sato et al. 2004, 1143). Likewise, the first sentence of Ganis et al. (2004, 226) declared that "During visual imagery, perceptual information is retrieved from long-term memory, resulting in the subjective impression of 'seeing with the mind's eye'." Meanwhile in Set-H, the first sentence from Korsnes et al. (2010, 610) declared that "Auditory hallucinations in schizophrenia may be regarded as speech perceptions without an external acoustic input, which trigger a perceptual misrepresentation". Likewise, Gavrilescu et al. (2010, 1149) introduced AVHs through the common description of them "as 'real voices' in the absence of any real external auditory stimulation".

Considered side-by-side, these definitions highlight the contemporary currency of typical characterisations of both mental imagery and hallucinations: mental images are voluntary introspective SLMP that resemble perception; hallucinations are spontaneous SLMP that are confused for perception. Even so, characteristics of the type of SLMP of interest were not always provided. In such cases, familiarity with the type of SLMP conceptualised as either mental imagery or hallucinations was simply taken for granted.

On the one hand, it was assumed that everyone can conjure mental imagery at will; meanwhile hallucinations were simply synonymous with dysfunction. Starting with Set-M, there was often an expectation that experiences of voluntary auditory SLMP were common to all. This expectation is emphasised by the instructions Halpern et al. (2004, 1281) gave to their readers: "imagine a song, perhaps *Happy Birthday,* first as played by piano, and then by a trumpet". Similarly, Kana et al.(2006, 2484) began their abstract by explaining that during the comprehension of "high imagery sentences like *The number eight when rotated 90 degrees looks like a pair of eyeglasses*… the linguistic content must be processed to determine what is to be mentally imaged, and then the mental image must be evaluated and related to the sentence".

In contrast, within Set-H the SLMP investigated were of interest precisely because they were considered abnormal. Even when described only by the overlapping core definition shared with mental imagery, hallucinations were presented as an undesirable symptom of pathology. For example, hallucinations were described as the most typical and disabling symptom of schizophrenia (Amad et al. 2014, 184); and as symptoms reported by "over half of all patients with Parkinson's disease" (Shine, Halliday, et al. 2014, 2207).

These structured associations can also be found in those articles where the type of SLMP investigated was not defined at all. In such cases, contextual descriptions drew on an expected familiarity with the concepts of mental imagery (as used to investigate various cognitive functions) or hallucinations (as used to investigate various pathological conditions). Indeed, the expectation that each concept individuates the type of SLMP of interest was maintained even after one or more of the characteristics once intended to explain this distinction had been abandoned. For example, even when allowing that mental images can be experienced as vivid re-experience of perception, these SLMP were still considered to merely *resemble* perception. This can be seen in the description of mental imagery in Zvyagintsev et al. (2013, 1421) as "characterised by a vivid re-experience of previously viewed visual material, heard auditory content or perceived other types of sensory information". In this article, the high degree of perceptual similarity was presented alongside the presentation of mental imagery as "a complex cognitive process that resembles the experience of perceiving an object when this object is not physically present to the senses" (Zvyagintsev et al. 2013, 1421). Conversely, multiple typical characteristics of hallucinations can be discarded while still being considered symptomatic of dysfunction. For example, in introducing an experiment on AVHs, Ford et al. (2009, 58) described these as a symptom of "75% of people diagnosed with schizophrenia [and experienced] as "voices ranging from random and/or muffled words to complete sentences [reported as] either internal (coming from inside their head) or external, and … as real despite evidence to the contrary".

Recalling Chapters Three and Four, the flexibility in the degree of reliance on typical characteristics further emphasise how the independent uses of the concepts of mental imagery and hallucinations is at odds with the long-recognised difficulty of reliably distinguishing between ordinary and abnormal SLMP. This tension highlights how these independent uses are structured by the entrenched associations within which the typical characteristics emerged rather than the characteristics themselves. For instance, while these contextual descriptions ignored the typical characteristics, they still carried the association that once justified the inverse characterisations of mental imagery and hallucinations.

Contrasting yet another example from each article-set reiterates this point. Firstly, Bien et al. (2014, 231) described the "ability to generate, inspect, evaluate, and manipulate, visual images in the absence of physical stimulation [as a set of] processes that at least mediate, if not constitute several core functions of human cognition". In contrast, the high prevalence of visual hallucinations among dementia patients was taken by Taylor et al. (2012, 491) as a clinical feature that "strongly suggests that the visual system [in these patients] is dysfunctional". Once again, SLMP conceptualised as mental images are assumed to involve an ordinary process of recalling and recombining perceptual experiences in aid of abstract thought; SLMP conceptualised as hallucinations are assumed to involve some disruption of an individual's ability to correctly process perceptual information.

In the remainder of the articles from both sets, the concept used was taken to be a familiar tool for investigating the type of function/dysfunction being investigated. Firstly, when the concept of mental imagery was used without a definition it was introduced in relation to its (presumed) role as crucial for imagination, memory, reasoning, or language processing. For example, Just et al. (2004, 112) open their article with the statement that

“Many types of thinking, particularly language comprehension, entail the use of mental imagery”. Despite mental imagery playing a key role in their experimental aims, Mechelli et al. (2004, 1257) took the expectation of familiarity with this concept even further by only introducing the concept of mental imagery in passing (as one of a number of cognitive processes that have been correlated with neural activity in category-responsive brain regions). Secondly, when the concept of hallucinations was used without a definition, SLMP were introduced by a relational description emphasising their role as a symptom of pathology. For example, the opening sentence of Ramírez-Ruiz et al. (2008, 2335) draws on past investigations that have “reported the presence of complex visual hallucinations (VH) in about 25% of patients with Parkinson’s disease (PD)”. Likewise, Escartí et al. (2010, 31–32) only mention hallucinations in the fourth paragraph of their main article in relation to the “prosodic deficits” in schizophrenic patients (despite later including hallucinations as key concept in their reported methods).

To summarise these trends, few articles offered a definition of the SLMP being investigated; and those definitions offered were cursory at best. Even allowing for more informal descriptive definitions, the number of articles from each set explicitly describing the characteristics of the SLMP of interest was still less than 50%.[180] Instead, the concepts of mental imagery and hallucinations were each taken to reliably individuate a discrete type of SLMP. The associations underlying this expectation were routine; offered without any justification other than the implicit assumption that some SLMP (mental imagery) are required for neurocognition while other SLMP (hallucinations) are symptomatic of neurocognitive dysfunction.

[180] The proportion of articles within each set providing definitions was higher within Set-M (48%) than in Set-H (33%).

7.1.2 Selecting Experimental Subjects

All articles reported requiring the voluntary participation of adult human subjects who met a set of comparable minimum criteria, including requirements for normal (or corrected-to-normal) vision and an absence of any neurological disorder, head trauma, or substance dependence. The majority of articles within both Set-M and Set-H also reported the sub-population from which their subjects were recruited, as well as the proportion of subjects with expected variables (such as hand-dominance, gender, age, and education).[181] Alternatively, in some studies these variables were reported as proportions of the whole, or as balanced within the test group and/or as matched between groups (e.g., Amad et al. 2014; Doucet et al. 2012).

While sharing these standard practices for recruiting and selecting experimental subjects, other selection criteria differed depending on whether the SLMP of interest was conceptualised as mental imagery or hallucinations. When the concept of mental imagery was used, an ordinary experience of SLMP was expected to be available for investigation by recruiting healthy subjects (without necessarily clarifying what counts as 'healthy'). Whereas, recruiting from specific clinical sub-populations was taken to be the most productive way to isolate the hallucinatory experiences of interest.

These expectations are evident in the documented subject recruitment and selection practices. Beginning within Set-M, experimental subjects were almost always from the general (non-clinical) population – often recruited from tertiary student populations or from volunteers described simply as healthy or normal.[182] Little if any additional information was

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[181] A number of experiments only included male right-handed subjects (e.g., Bird et al. 2010; Lamm et al. 2007; Mechelli et al. 2007; Zhang, Hao, et al. 2008; Zhang, Shi, et al. 2008).

[182] For examples of this, see: (Bird et al. 2010; de Borst et al. 2012; Ganis, Thompson, and Kosslyn 2004; Halpern et al. 2004; Just et al. 2004; Kaas et al. 2010; Slotnick, Thompson, and Kosslyn 2012; Wais et al. 2010).

included beyond the criteria shared by articles across both sets. However, when specified, inclusion criteria often required sufficient performance in an experimental task (that was considered to require the subjects to use mental imagery); while subjects with prior psychiatric diagnoses were excluded.[183]

In the unusual event that the experimental subjects in Set-M were recruited from clinical populations, there was still an expectation that subjects would experience the ordinary mental imagery assumed to be required for normal cognitive function. For example, Kana et al. (2006) recruited two groups of subjects – high-functioning individuals diagnosed with autism and a control group of ordinary community volunteers. Both groups consisted of subjects who were expected to use imagery to solve a language comprehension task.

This routine association between imagery and cognitive performance reflects the broader trend within Set-M: during their subject selection processes for experiments documented within Set-M, subjects selected were typically assumed to be able to generate mental imagery if they completed the set task. Indeed, only two articles verified mental imagery experiences as part of subject selection (both via a questionnaire). From their questionnaire, Halpern et al. (2004, 1283) found that, when rating the vividness of an imagined auditory stimuli, the average score for all volunteers was within the middle of a scale from 'no image' to 'very vivid'. Whereas, Guillot et al. (2009, 2160) selected only those 13 out of their 50 healthy volunteers that "were rated as good to excellent imagers" on their questionnaires. Recalling the wide range of variability of SLMP discussed in Chapter Three, the questionnaire responses in these two articles highlights that taking the variability of mental imagery experiences into consideration was not a routine practice; when included at all, only a small set of variables were considered.

[183] For examples, see: (Lamm et al. 2007; Sato et al. 2004).

Turning to Set-H, subjects were primarily recruited from specific clinical sub-populations. The most common recruitment populations consisted of patients diagnosed with a specific disorder – such as schizophrenia, Parkinson's disease and, less commonly, epilepsy or dementia. Part of this selection usually involved further clarifying that subjects selected from these diagnosis-specific populations had a clinical history of hallucinations. For example, van de Ven et al. (2005, 646) selected paranoid schizophrenic patients based on the DSM-IV criteria; adding that these subjects "predominantly suffered from auditory verbal hallucinations that consisted of running commentary with derogatory content".

In some cases, subject selection involved using clinical measurements to verify that hallucinations were one of the symptoms experienced as part of the disorder in question. These instruments for determining the presence of hallucinations were typically one minor element in a broader diagnostic assessment: including various 'positive symptom' scales for schizophrenia (Kay, Fiszbein, and Opler 1987; Andreasen 1983); the *Neuropsychiatric Inventory* questionnaire for dementia (Kaufer et al. 2000); and the *Unified Parkinson's Disease Rating Scale* (Goetz et al. 2007). Often, documentation of this processes was limited to mentioning that subjects were assessed using the relevant symptom scale. However, in some cases, detailed descriptions of SLMP were provided. For example, Yao et al. (2014) reported using the *Parkinson's Psychosis Rating Scale* to elicit detailed descriptions of the visual hallucinations experienced by subjects. These detailed description were used to ensure that subjects were only selected if they reported "seeing [their hallucinations] as well-formed persons, animals or objects" over a four-week period or more (Yao et al. 2014, 5659).

In addition to verifying the presence of hallucinations with diagnostic measurements, several articles in Set-H included focused introspective questionnaires. This extra step detailed specific characteristics of the hallucinatory experiences being investigated. For example, Korsnes et al. (2010, 611–12) developed eleven questions focusing on the duration, frequency, timing, modality, emotional-valence, and content of hallucinations. Taking a more formal approach, Diederen et al. (2010, 428) used the auditory hallucinations subscale of the *Psychotic Symptom Rating Scale* (PSYRATS) to provide a detailed assessment of the characteristics of SLMP experienced by their subjects. Although not documented in these articles, characteristics typically assessed by the PSYRATS hallucination subscale include frequency, duration, loudness, level of control, as well as the subjects' beliefs about the source of these SLMP and any distress or disruption that these experiences caused (Haddock et al. 1999, 883–84). While taking an equally formal approach, Vercammen et al. (2011, 1010) used the *Auditory Hallucinating Rating Scale* (AHRS) to focus only upon the SLMP characteristics of "loudness" and "[sense of] reality".

Along with these additional questionnaires, articles in Set-H sometimes documented a range of additional criteria for determining which participants were selected from these diagnostic-specific populations. For example, subjects were only selected if the hallucinations they reported met certain criteria: single-modality hallucinations (Amad et al. 2014; K. M. J. Diederen et al. 2013); high hallucination severity scores (Ćurčić-Blake et al. 2013; Escartí et al. 2010); or a sufficient frequency and/or perceptual similarity (van Lutterveld et al. 2014; Ralph E. Hoffman et al. 2007). Alternatively, subjects experiencing hallucinations that did not fit within the experimental design were excluded from selection. For example, in one case subjects were excluded if they reported hallucinatory content that ran parallel to ordinary thoughts (Kelly M.J. Diederen et al. 2010). In other cases, subjects were excluded if their hallucinations were either insufficiently frequent (Ramírez-Ruiz et al. 2008), or not sufficiently intermittent (van Lutterveld et al. 2014).

In the few experiments that recruited participants without relying on specific diagnostic categories, typical characteristics associated with hallucinations played an even more prominent role in subject selection. For example, Raij et al. (2009, 2995) recruited volunteers who had experienced hallucinations by targeting psychiatric outpatients and third-sector association members; of these volunteers, subjects were selected based on their responses to various questionnaires intended to measure the perceptual similarity and subjective reality of hallucinations. Likewise, recruiting both test and control subjects from a website, van Lutterveld et al. (2014, 1437) specified that selection only included subjects with non-psychotic AVH experience intermittent 'voices' that "had a 'hearing' quality".

Regardless of whether subjects were recruited from clinical or non-clinical populations, the inverse characterisations of mental imagery and hallucinations were a key element in individuating the type of SLMP investigated. In the case of hallucinations, the type of SLMP investigated were those characterised as symptomatic of dysfunction (whether clinically-relevant or not). These characterisations of sub-clinical dysfunction implicitly rely upon older distinctions between non-pathological hallucinations and mental imagery (discussed in Chapter Four).

These characterisations can be seen in descriptions of the similarities between the characteristics of AVHs in clinical and non-clinical populations. For example, comparing clinical and non-clinical AVHs, Diederen et al. (2013, 1686) reported that the experiences of AVHs in non-clinical populations differed in the emotional content and controllability compared to clinical AVHs; while "aspects of AVH, such as the perceived location of the voices, the number of voices, loudness, and personification, were similar for both groups". Despite these similarities, non-clinical subjects experienced "little discomfort from their AVH [and] showed no social, affective or professional dysfunction" (K. M. J. Diederen et al. 2013, 1687). Nonetheless, Diederen et al. (2013, 1687) described subjects with non-clinical AVHs as holding "an intermediate position on the psychosis continuum". Building on this view by drawing on prior research, Diederen et al. (2013, 1687) suggested that the AVHs in psychotic and non-psychotic individuals might have "the same neurobiological mechanism".

When compared, the recruitment and subject selection practices documented for experiments using the concepts of either mental imagery or hallucinations clearly drew upon entrenched expectations about functional and dysfunctional forms of SLMP. Experiences of ordinary mental imagery were typically assumed to be available for investigation by recruiting 'healthy' subjects. Whereas investigations documented within Set-H specifically selected subjects based on pathological symptoms: either their history with a specific modality of hallucinatory experiences associated with a disease; or the reported characteristics considered typical of pathological hallucinations (regardless of whether subjects were drawn from clinical or non-clinical populations). Even when selecting non-clinical subjects, the concept of hallucinations was used to individuate experiences of SLMP considered dysfunctional (regardless of whether the SLMP was experienced as distressing).

These same associations are also evident when participants were recruited from a single population and then divided into separate subject groups. Firstly, when this approach was taken within Set-M, participants were still recruited from some section of the 'healthy' population and then assigned into comparative groups based upon the expected role of imagery in a specific cognitive function. For example, volunteers were separated into male and female groups to investigate the role of imagery in explaining proposed sex-linked differences in visuospatial processing (Butler et al. 2006). In another study within Set-M, the role of imagery in making judgements based on perceptual information was investigated by recruiting ordinary participants and randomly allocating them to one of two groups – one group was asked to imagine a remembered face prior to making a judgement about it, while the other group made these judgements without being asked to use imagery (Diekhof et al. 2011).

In contrast, when this type of group-selection approach was reported within Set-H, all subjects were recruited from a specific clinical sub-population. In such cases, their division into two groups was based on the type of hallucinatory experience (or not) that these subjects reported. For example, Hoffman et al. (2007) recruited all their participants from the same diagnostically determined population and divided these subjects into two groups to be investigated separately: those with continuous hallucinations, and those with intermittent hallucinations. Similarly, Amad et al. (2014) recruited all their subjects from a population of patients with the same diagnosis and then split these into two comparative groups depending on whether they experienced single modality (visual) or multi-modal (visual and auditory) hallucinations. Likewise, recruitment for the experiment documented by Shine et al. (2014) was based on a set diagnosis; these subjects were then allocated to different groups based on their Bistable Percept Paradigm (BBP) test score (which is thought to indicate the presence or absence of visual hallucinations).

Comparing these practices for recruiting and selecting experimental subjects illustrates the routine expectation that the concepts of mental imagery or hallucinations individuate discrete types of SLMP. This expectation was rarely explicit and never justified. Given this, the variability in both ordinary and pathological SLMP (and the difficulty of reliably delineating between desirable and undesirable SLMP more generally) went unacknowledged. Instead, each concept was used independently of the other in investigations that contributed to the pursuit of different goals. All healthy subjects were expected to experience mental imagery and, as such, no confirmation of SLMP experiences was required for subjects to be included in the experiments documented within Set-M. Based on these expectations, selecting subjects from the general population was considered sufficient to individuate ordinary experiences of SLMP for the purpose of investigating the role of these phenomena in neurocognitive function. Whereas, in Set-H, subjects were typically sought out in clinical sub-populations; even when recruited from the general population, subject selection relied on typical characteristics associated with hallucinations. Selecting subjects in this way operated to individuate specific varieties of abnormal SLMP with the goal of investigating the dysfunction explaining the role of these SLMP in various neurocognitive disorders.

7.1.3 Additional Verification of SLMP Experiences During Experiments

With subjects selected in this way, the SLMP of interest was taken to be successfully individuated. The functions involved in mental imagery were assumed to be identifiable in healthy subjects if they undertook an appropriate task. Conversely, the dysfunctions responsible for hallucinations were typically assumed to be identifiable in those subjects with a diagnosis incorporating hallucinatory symptoms. The role of these assumptions during the experimental conditions will be considered in a moment. However, before turning to these, it is worth considering the small minority of articles within both Set-M and Set-H that documented additional procedures for verifying that their subjects experienced SLMP *during* the fMRI experiments.

Within Set-M, during-scan verification sometimes required subjects to describe typical characteristics of mental imagery. For example, Bird et al. (2010, 1169) reported that during the fMRI scan participants were required to indicate when they had "formed a clear image [of the given environment]" and then to "rate the vividness of their imagined scene". Likewise, Zvyagintsev et al. (2013, 1423) asked subjects to rate the vividness of their mental imagery, as well as the effort required to form that image. Alternatively, the presence of mental imagery during fMRI scans was inferred from behavioural results about task performance. For example, Kana et al.(2006, 2487) did not instruct subjects whether to use imagery (or not) in their language-comprehension strategies for each condition. Instead the experimental design relied on the assumption that comprehending some sentences requires mental imagery (condition one) while comprehending other sentences does not (condition two) (Kana et al. 2006, 2487). Similarly, Butler et al. (2006, 446) instructed subjects to mentally rotate one figure into alignment with a second figure in order to make judgements about two visually present figures. Rather than verifying that mental imagery was used, Butler et al. (2006, 451) took "the expected increasing reaction time and decreasing accuracy with increasing angle of rotation [required for mentally rotating a visual image, as] confirming that subjects were appropriately engaged in the task". This expectation ignores the possibility that subject completing this task without experiencing mental imagery may vary in reaction times also.

In line with this, follow-up verifications were partial and only included within Set-M as an afterthought. For example, Just et al. (2004, 115) reported that, although unprompted, one third of participants commented during their post-scan debrief "that they 'visualised' or 'built a mental picture' to perform the high-imagery condition". Likewise, Kaas et al. (2010, 796) reported that their subjects found the task "difficult, but they did manage to perform the task using mental imagery". Similarly, Bunzeck et al. (2005, 1120) reported that there was no need to provide training on the imagery-task because all of their subjects "verbally reported that they were easily able to imagine the typical sounds coming with the movies".

Within Set-H, verification procedures were even more uncommon. Indeed, reporting the presence of SLMP during an fMRI scan was often considered a limiting aspect of the design, or was presented as a carefully-justified minor part of the overall experiment. For example, van de Ven et al. (2005, 646, 652) asked subjects to indicate the duration of any hallucinations experienced during the fMRI scan; then explained-away the unexpected result (differences between the timing of STG activity and the duration of hallucinations). This explanation suggested that the subjects were unable to comply with the instructions – a problem explained, in turn, by the difficulty of distinguishing hallucinations from reality (van de Ven et al. 2005, 646, 652). Similarly, Gavrilescu et al. (2010, 1155) instructed subjects to indicate the presence of any hallucinations experienced during the fMRI scan and, as none did so, noted that the "deficits reported… are trait effects specific to a lifetime history of [auditory hallucinations]". Further highlighting this trend, Goetz et al. (2014, 116) reported that, to their knowledge, their study was "the first reported case… using fMRI techniques in a [Parkinson's disease] patient during actual visual hallucinations". Furthermore, of those few articles within Set-H that documented post-scan verification of SLMP, half explicitly required that subjects had *not* experienced hallucinations during the scan (K. M. J. Diederen et al. 2013; van Lutterveld et al. 2014).

This lack of interest in hallucinations being present during fMRI scans highlight the expectation that hallucinations are due to a dysfunction that exists in an individual regardless of whether an acute hallucinatory experience is present or absent. This suspicion that subjects might not provide reliable indication of the presence/absence of hallucinations limited the value of these verification steps. Any attempts to verify hallucinations during fMRI scans (in addition to any verification during subject selection) focused primarily on the duration and frequency of these experiences; often emphasising other typical characteristics of hallucinations – particularly, a lack of control. These practices reflect the associations between hallucinations as a dysfunction of judgement: how could subjects be trusted to report when they experienced hallucinations if, by definition, these SLMP are as *compelling* as perception? An expectation that does not reflect the reported experiences of SLMP diagnosed as hallucinations (as detailed in Chapter Three and Four).

Once again, the implicit associations embodied by the concepts of mental imagery and hallucinations structured their uses as tools for investigating SLMP in neuroimaging experiments. In this case, the entrenched mediator-view associations were instrumental in verifying if, when, and how, to verify that the subjects studied actually experienced the SLMP of interest. When the concept of mental imagery was used, the expectation was always that subjects could – if asked – reliably report on their voluntary/effortful/controlled experiences of SLMP; experiences assumed to be required for (at least some) aspects of thought. In contrast, the expectation that it is impossible to distinguish hallucinations from perceptions due to perceptual similarity and failures in judgement, meant that subjects were rarely trusted to be able to report on their experiences of spontaneous SLMP.

7.2 Experimental Aims

There was a range of different aims documented for the individual neuroimaging experiments examined.[184] For this analysis I have sorted these into four broad types: theory-dependent aims; theory-polyvalent aims; exploratory aims; and contextual aims. I will offer examples of each of these before discussing the trends in how the concepts of mental imagery and hallucinations each contributed to these experimental aims.

Theory-dependent aims tested a hypothesis drawn from existing theories about either mental imagery or hallucinations. An example from Set M is the article by Ganis et al. (2004, 226) where the ‘analog theory’ of visual mental imagery was tested by investigating a specific hypothesis: that neuroimaging techniques would show a “substantial overlap in neural activation during visual mental imagery and visual perception”. Meanwhile, within Set-H, Ford et al. (2009, p.58-59) sought to “test the theory that voices would compete with external sounds for auditory processing resources”. In testing this theory, Ford et al. (2009, p.58-59) adopted the view that hallucinations stem from a “fundamental dysfunction… whereby old memories, preoccupations, and thoughts are interpreted as coming from an external source”.

Theory-polyvalent aims sought to extend prior research into SLMP without seeking to examine any specific theoretical views about these phenomena.[185] For example, Halpern et al. (2004, 1283) designed their experiment to test a working hypothesis that, if auditory areas

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[184] The type of aims documented within Set-M and Set-H were identified via the hypotheses these experiments were intended to test and/or the specific impetus or goal reported for those experiments not testing hypotheses.

[185] The uses of concepts in experiments independently of specific theories has been examined elsewhere, for examples see: (Arabatzis 2012; Arabatzis and Nersessian 2015; Steinle 2010b, 2016; Schmidgen 2014).

are involved in evoking musical imagery, timbre imagery would correlate with activity in the secondary auditory areas. In addition, Halpern et al. (2004, 1283) also made a point to predict that timbre imagery would elicit activity in the IFG ("as all imagery tasks have some memory component associated with them") but not in the motor cortex (because timbre imagery "should involve neither subvocalization nor other sequencing of events"). These predications were drawn from prior research into the neuroanatomical correlates of both auditory and visual imagery rather than specific theoretical explanations for the role of SLMP in neurocognition. Within this context, the two prior studies on timbre imagery were taken as providing "results [that] give us confidence that timbre imagery is a real phenomenon" (Halpern et al. 2004, 1282). Therefore, as a type of phenomena worth investigating, Halpern et al. (2004, 1282) focused on two specific aims: "one aim…was to expand our knowledge of timbre imagery using a different technique [while a] second aim was to investigate the neural substrate of timbre imagery".

Another example of theory-polyvalent hypothesis testing, this time from Set-H, is provided by Diederen et al. (2013). In this example, conflicting theories of the pathogenic mechanism underlying hallucinations were discussed – including proposals for dysfunction in either language-perception or memory – and then a hypothesis was presented that was not intended to test either theory. Instead of testing these theories, the differing ROI implicated in each theory were taken as starting-point regions for investigating resting-state connectivity in non-psychotic subjects with a history of AVHs (K. M. J. Diederen et al. 2013, 1686).

Exploratory aims, in contrast, did not set out to test a hypothesis at all.[186] Instead, these individual experimental aims seek to gather data on potential correlations, develop new techniques, and so on. In the articles examined, experiments with exploratory aims focused

[186] See Appendix 1 (Annotated Glossary) for how *exploratory aims* in individual experiments relate to broader notions of exploratory experiments (Burian 1997, 2013; Steinle 1997, 2016).

on examining the neuroanatomical correlates of *specific aspects* of SLMP to generate more data and/or develop new experimental techniques. For example, in Set-M, Rudner et al. (2005, 86) detailed how their experimental design was novel – "[setting] out to increase our knowledge of the mechanisms involved in dynamic manipulation of auditory mental imagery under taxing conditions [rather than to test specific hypotheses]". In this case, the aim was to explore how the effect (SLMP-neuroanatomical-correlates) changed in relation to specific variables (taxing conditions). In other cases, the aim was to explore how distinct the effect of interest (SLMP-neuroanatomical-correlates) was from other effects (such as memory-neuroanatomical-correlates). For example, after pointing out the lack of evidence "for arguing, *a priori* that visual memory and visual mental imagery are mediated by the same or different neural substrates" Slotnick et al. (2012, 14) conducted their experiment "to obtain empirical evidence [that could provide] traction on this issue".

Exploratory aims were also evident in Set-H. For example, van de Ven et al.(2005, 647, 651) took a data-driven approach; localising increased activity in the auditory cortex during hallucinatory experiences to compare with similar localised increased activity during auditory perception.[187] Once again, the aim was to explore how the effect of interest (SLMP-neuroanatomical-correlates) related to a specific variable (perceptual stimuli). Likewise, Stebbins et al. (2004, 1409–10) compared perception of movement in matched subjects with and without visual hallucinations to explore the relationship between the effect of interest (SLMP-neuroanatomical-correlates) and a specific disease (Parkinson disease).

Contextual aims were different again. Experiments in this category investigated SLMP-neuroanatomical-correlates as a necessary step in investigating the role of SLMP experiences

[187] In addition to taking an exploratory approach, van de Ven et al.(2005, 647, 651) also presented their data-driven techniques as a way to investigated the neural correlates of hallucinations without relying on self-reports for determining the presence of hallucinatory experiences. I will return to this point later.

within another context. Typically, this context was provided by broader social-psychology questions or medical treatments. As such, rather than seeking to make a novel claim about the role of SLMP in neurocognitive function/dysfunction, the role of SLMP in neurocognitive function/dysfunction was of interest in relation to a broader question. For an example from Set-M, Butler et al. (2006, 445) investigated the neuroanatomical correlates of visual imagery (as used in mental rotation tasks) because it provided a "probe for investigating the neurobiological underpinnings of sex differences in cognition". Likewise in Set-H, Hoffman et al. (2007, 2733) commented that the "pathophysiological basis of [schizophrenia] remains uncertain, but if better understood, may lead to more effective treatments". With this motivation, Hoffman et al. (2007, 2734) designed experiments to identify brain regions where the relationship between clinical treatment and symptom improvement could be analysed using SLMP-neuroanatomical-correlates.

As just outlined, there were several types of aims documented for the experiments examined. However, regardless of the relationship between theory and experiment, these aims always drew upon a specific conceptualisation of the SLMP investigated (mental imagery or hallucinations). This can be illustrated by comparing those aims investigating the perceptual similarity of experiences of SLMP. As expected for investigations of SLMP, questions of perceptual-similarity were often central to the aims of experiments using the concepts of either mental imagery or hallucinations. Despite this expected intersection, the experimental aims relating to the perceptual similarity of SLMP differed depending on the concept used in the experiment. In the examples drawn from Set-M, experimental aims focused on exploring potential overlaps between imagery and perceptual processes (Ganis, Thompson, and Kosslyn 2004; Halpern et al. 2004; Slotnick, Thompson, and Kosslyn 2012) or identifying the mechanism underlying the contribution of imagery to language processes (Rudner, Rönnberg, and Hugdahl, K 2005). Whereas, in examples drawn from Set-H, experimental aims focused on identifying the dysfunctional perceptual processes underlying hallucinatory experiences (Ford et al. 2009; Stebbins et al. 2004; van de Ven et al. 2005). In both sets of articles, the type of relationships between SLMP experience and perception were presupposed: mental images were expected to function alongside perception, while hallucinations were necessarily dysfunctional perceptions.

The value of using the concept of either mental imagery or hallucinations was rarely justified. It was taken for granted that the concept used successfully individuated the type of SLMP of interest. The entrenched associations supporting this assumption provided the same background knowledge regardless of whether the experiment aimed at exploration, testing a theory-polyvalent hypothesis, or testing a theory-dependent hypothesis. Drawing these examples together also highlights how experimental aims relied, to varying degrees, on familiarity with the concept used for individuating the SLMP of interest. Furthermore, regardless of the degree of familiarity expected, these aims reflected the entrenched associations about SLMP that structure the independent uses of each concept. Mental imagery provided a concept for a discrete type of ordinary SLMP, that can be investigated independently of the research into those discrete pathological experiences of SLMP conceptualised as hallucinations, and vice versa.

As detailed in Chapter Four, these mediator-view associations structured the uses of the concepts of mental imagery and hallucinations for investigating discrete epistemic goals. Reflecting this, mental imagery operated as a conceptual tool for investigating ordinary SLMP within various neurocognitive processes. At the same time, the concept of hallucinations operated as a conceptual tool for investigating the dysfunctional neurocognition that might explain these symptoms of pathology. These experimental aims reflect the structured uses of each concept. When the concept of mental imagery was used, the broader epistemic goal of understanding ordinary function set the standards for the types of experimental aims pursued within Set-M. For example, the main aims reported in Set-M focused on examining the mechanisms that might underlie the perceptual resemblance of mental imagery and/or the role of these SLMP in cognitive functions such as memory and language processes. Meanwhile, the concept of hallucinations was always used for investigating the broader epistemic goal of identifying disordered causes for SLMP. This goal set the standards for the types of experimental aims pursued within Set-H. For example, one of the main aims reported in Set-H focused on identifying the mechanism causing the dysfunctional perceptual processes responsible for hallucinations.

7.3 Experimental Conditions

Within Set-M and Set-H, most articles described experimental conditions that required subjects to follow specific instructions during the fMRI scanning procedures. Broadly speaking, the instructions given to subjects during the fMRI scan for the main experimental condition can be considered to fall into four task types. I will refer to these as SLMP presence tasks (requiring subject to report the presence of SLMP experiences during the scan); internal-judgement tasks (requiring recalling/imagining perceptual experiences); external-judgement tasks (requiring subjects to make a judgement based on presented perceptual stimuli); and resting-state tasks (requiring subjects to rest without falling asleep).

The choice of task for a given experimental condition can each be related to the aims discussed earlier. However, it is important to note that each type of task was used in relation to a range of experimental aims (both within each article-set and between them), and that each of these aims contributed to the broader epistemic goal embodied by the structured uses of each concept as experimental tools. For example, tasks requiring subjects to attend to their SLMP were common in experiments using the concept of mental imagery with the aim of investigating the shared mechanisms underlying mental imagery and perception (Bunzeck et al. 2005; de Borst et al. 2012; Johnson and Johnson 2014; Reddy, Tsuchiya, and

Serre 2010; Zvyagintsev et al. 2013). However, SLMP presence tasks were also used in relation to the role of mental imagery in memory (Guillot et al. 2009; Mechelli et al. 2004). In addition, SLMP presence tasks contributed to the epistemic goal of identifying those SLMP-neuroanatomical-correlates relevant to dysfunctional hallucinations – whether through experiments that aimed to investigate perceptual processes (Goetz et al. 2014; Ralph E. Hoffman et al. 2007; Raij et al. 2009; van de Ven et al. 2005) or language processes (Kelly M.J. Diederen et al. 2010; Ralph E. Hoffman et al. 2011).

The same type of task was also used in relation to different experimental methods, such as within-group and between-group studies. In within-group studies, the fMRI scans during the experimental task were compared with the fMRI scans for another task for individuals within the same group. For example, the fMRI scans during an SLMP presence task was often compared to the fMRI scans for the same subjects during a perceptual task. In between-group studies, all subjects were given the same task and the fMRI scans during this task were compared between separate groups of these subjects. For example, scans were acquired for two or more different subject groups while each completed the perceptual task and then these were compared. In either type of design, comparative experimental data was typically reported for the fMRI scans acquired during the main task as compared to the fMRI scans acquired during one or more comparative conditions (regardless of whether these comparative conditions involved the same-subjects/different-task, or for different-subjects/same-task).

This main task was a central feature in the design and implementation of these experiments and, for my present purpose, it is worth comparing the experimental condition tasks in their own right. Of the types of tasks indicated above, SLMP presence tasks were documented in about 30% of the articles in Set-M and about 22% of articles within Set-H. However, internal-judgement tasks based on recalling/imagining perceptual experiences were far more common in Set-M (57%) than Set-H (4%). Whereas, external-judgement tasks based on perception were far more common in Set-H (52%) than in Set-M (9%). Likewise, resting-state tasks were also far more common in Set-H (22%) than Set-M (4%).

The contrasting dominance of internal-judgement tasks for investigating mental imagery and external-judgement tasks for investigated hallucinations highlights the inverse association embodied by these concepts. While mental imagery experiences are characterised as internal SLMP that are useful in memory/imagination, hallucinations are characterised as unacceptably like external perception and, therefore, as a symptom of dysfunction. However, while the disproportionate use of certain types of experimental tasks within each set is revealing in and of itself, the ways these types of tasks were employed within each set provides a more nuanced view of these differing proportions. As such, I will now offer examples of each of these task-types in turn.

7.3.1 SLMP-presence Tasks

The first type of experimental tasks to consider are those expecting subjects to experience SLMP during the fMRI scan without being asked to inspect, manipulate, judge, or otherwise use these SLMP. Of the articles documenting this type of task, experiments in Set-M expected subjects to follow cues to deliberately generate vivid content-specific imagery, while articles in Set-H had much lower expectations – merely asking subjects to indicate the presence/absence of any hallucinatory experience spontaneously generated during the fMRI scan. A selection of examples from each set will illustrate this difference.

Within Set-M, instructions were given for subjects to generate voluntary imagery with the expectation that they could choose the content and the degree of perceptual-similarity of these SLMP. In Mechelli et al. (2004, 1257) subjects were instructed to "generate vivid images of familiar houses, faces and chairs… and press a button when ready with a vivid image". Bunzeck et al. (2005, 1120) asked subjects to watch a silent movie and "imagine the appropriate sound as intensely as possible". Similarly, in Johnson et al. (2014, 3) subjects were instructed "to form the most vivid and accurate mental image [of a named picture] as long as the label was onscreen". These instructions were based on the expectation that ordinary subjects could generate content-specific sensory-information on cue. At the same time, additional requests for vivid imagery were explicitly within the context of voluntary SLMP; there was no mention that these SLMP might be confused for actual perception. This illustrates the expectation that, when *appropriately controlled,* SLMP with a high degree of perceptual similarity can be useful for accurately representing sensory information.

Compared to the complex instructions given to subjects within Set-M, the SLMP-presence task within the Set-H carried simple instructions: to rest and indicate the presence of any hallucinations experienced during the fMRI scan. In contrast to Set-M, the expectation that subjects would actually experience SLMP during the scan was supported by their subject-selection procedures. For example, Goetz et al. (2014, 115) reported that they chose the task for the experimental condition "on the premise that [the subject] would potentially hallucinate during an fMRI scan"; a premise supported by the intermittent presence of unbidden hallucinations during clinical observation (Goetz et al. 2014, 115). Based on the reports of subjects during selection, those reporting intermittent hallucinations were instructed to indicate the presence of SLMP by squeezing a handheld balloon (Kelly M.J. Diederen et al. 2010); pressing a button (Ralph E. Hoffman et al. 2007, 2011); or via some other response device (Goetz et al. 2014). For subjects reporting continuous hallucinations, no task was assigned as SLMP were present for the entire fMRI scan (Ralph E. Hoffman et al. 2007).

Differences in the instructions given to subjects in experiments with SLMP-presence tasks can be understood in relation to the mediator-view of SLMP. Within Set-M, mental imagery was considered a source of sensory information that could be generated at will.

Within Set-H, hallucinations were expected to be spontaneous and uncontrolled. These expectations are consistent with the traditional characteristics associated with ordinary and pathological SLMP respectively. At the same time, this task expects hallucinating subjects to recognise their SLMP *as SLMP* – an expectation that sits at odds with the typical characterisation of subjects with hallucinations as due to a lack of insight that SLMP are not perceptions. Instead, this approach is in line with the clinical descriptions of hallucinatory experiences retaining the compelling sense of reality even if recognised as unreal (discussed in Chapter Four). However, despite side-stepping this typical characteristic, others remained – notably, an expectation of high perceptual similarity and a lack of control over the hallucinatory experience. Whatever task details, the assumption was that these tasks isolated instances of experiencing either volitional SLMP (mental imagery) or spontaneous SLMP (hallucinations) for the purpose of investigating functional or dysfunctional neurocognitive processes respectively.

7.3.2 Internal-judgement Tasks

The internal-judgement task required a decision based on a remembered or imagined perceptual experience. Used more commonly within Set-M, examples included subjects being required to judge the angles between the hands on an imagined mental clock (Bien and Sack 2014, 233) or determine the degree of imagined mental rotation required to match-up two different pictures of the same 3D object (Butler et al. 2006, 446). Similarly, Ganis et al. (2004, 228) described their imagery scans as requiring subjects to keep their eyes closed, hear an auditory cue, "generate the corresponding visual image" from memory, wait for an auditory probe (4.5sec later), and perform "a corresponding judgement on the visualised object" (such as whether the object was taller than it was wide). An example in the auditory modality can be found in Halpern et al. (2004, 1284) where subjects were simply presented with the names of different musical instruments, asked to imagine the corresponding sounds of each, and then to rate their similarity on a one to five scale.

Meanwhile, there was only one experiment within Set-H that included a judgement task requiring a decision based on a remembered perceptual experience. There were three stages to this experimental task: a learning stage, an encoding stage (where subjects were presented with a series of numbers and asked to remember them), and a probe phase (where subjects were presented with various numbers and asked to judge whether these had been part of the encode phase or not) (Wible et al. 2009, 49). Of these, the final stage was of principal interest as it was during this stage that "memoranda were rehearsed and compared with those on the screen in order to make a response" (Wible et al. 2009, 51). Based on their findings, Wible et al. (2009, 52, 55) reported a correlation between the severity of hallucinations (as assessed by a symptom-scale during subject selection) and localised decreases in neural activity during this probe task. Wible and colleagues did not clarify whether there were any SLMP experienced during this task. Instead, having included a measure of the general severity of hallucinations experienced by subjects during subject-selection, Wible and colleagues inferred that correlations between these scores and a difference in neural activity during a judgement task would be related to the dysfunction underlying hallucinations. This correlation was then taken as evidence that dysfunctional working memory and language processing are involved in producing hallucinations.

Positioned in relation to the expectations that mental imagery is required for memory tasks, it is curious that the Wible et al. (2009) publication did not clarify whether experiences of SLMP (of any type) were experienced during the phase of rehearsing and comparing remembered perceptual stimulus. It becomes less curious when recognising that there was also no indication as to whether subjects reported using SLMP (or not) during internal-judgement tasks within Set-M. For example, Bien et al. (2014, 234) removed responses that were inaccurate (or an outliner in terms of time taken) from further analysis. This removal was reported without mentioning the possibilities that experiences of mental imagery may have been experienced by these excluded subjects; or the possibility that subjects retained may have completed the task correctly without any experience of mental imagery. Bien et al. (2014, 234) highlights that SLMP are expected to be a required element of memory, while Wible et al. (2009) takes this expectation and the associated inference, to assume that it is disruption of ordinary SLMP that threatens judgement about remembered perceptions. Rather than investigating an ordinary experience of SLMP as such, the internal-judgement tasks in Set-M conflated experiences of SLMP with the ability to accurately recall perceptual information. Conversely, rather than investigating dysfunctional experience of SLMP directly, the internal-judgement task reported in Set-H conflated SLMP with a combination of mental experiences (including delusions) considered to be the 'positive symptoms' of psychosis.

From this analysis, a relatively straight forward comparison can be made. Within Set-M, experiments employing internal-judgement tasks operated on the premise that carefully regulated mental imagery is crucial to the ability to make judgements based on remembered/imagined perceptual experiences. Within Set-H, a task requiring subjects to make a judgement (about remembered perceptual experiences) was considered relevant to investigating the relationship between hallucinations and dysfunction in memory and/or language comprehension. Positioned side-by-side, the internal-judgement task can be seen to rely on the concept used as typically characterised – even when these characteristics were not explicit.

7.3.3 External-judgement Tasks

The external-judgement tasks required subjects to make a judgement about actual perceptual experiences and were far more common in Set-H than in Set-M. However, as I have begun all other comparisons with Set-M, I will start with the two articles that used this type of task to investigate mental imagery. In these, the experimental tasks were intended to identify the role of mental imagery in either emotional judgement during perceptual processing (Diekhof et al. 2011), or language comprehension (Kana et al. 2006).

The experimental task documented by Diekhof et al. (2011, 1705) required subjects to imagine the facial expression anticipated in response to a cue (either positive, negative, or neutral) and then to evaluate the fearfulness of a visually presented facial expression (that did not necessarily match the cue). In the experimental task described by Kana et al. (2006, 2487), subjects were presented with sentences on a computer screen and asked to judge whether each sentence presented was true or false. The sentences presented were simple statements: such as, "*Oranges, pineapples and coconuts are all triangular in shape"* and *"Addition, subtraction, and multiplication are all math skills"* (Kana et al. 2006, 2486–87). The neural activity correlating to these sentence-comprehension tasks were analysed as two conditions: condition one consisted of those sentences categorised as high-imagery (i.e., those that normal subjects would require imagery to comprehend); condition two consisted of low-imagery sentences (i.e., those that normal subjects would not require imagery to comprehend) (Kana et al. 2006, 2487). From the two example sentences provided above, the first would be considered high-imagery – based on the expectation that healthy people would visualise an orange or a coconut and 'see' that they are not triangular.[188] The other example sentence, in contrast, would be considered low-imagery based on the expectation that healthy people would be able to judge the truth of the statement based on semantic information alone.[189] In both of

[188] This expectation ignores the possibility of people completing this task relying purely on semantic information that oranges and/or coconuts are not triangular.

[189] The expectation aside, being able to judge the truth-value of a sentence without imagery does not mean that you would not also experience imagery in relation to the sentence (perhaps 'seeing' the symbols for each mathematical operation).

these examples the actual use of mental imagery in judgement tasks was inferred from the ability to perform the task (rather than any confirmation of self-reported SLMP experiences during the fMRI scan).

In contrast, when an experimental task required subjects to make a judgement about perceived stimuli within Set-H, it was framed by the expectation that hallucinations indicate dysfunction within perceptual processes and/or language comprehension. For example, in Escartí et al. (2010, 33) the experimental task was intended to "replicate those emotions related to hallucinatory experiences" by having subjects listen to aurally presented words (pronounced with a tone matching the associated emotion) and later score the level of anxiety each word provoked in them. In Korsnes et al. (2010, 612) an experimental task intended to investigate hemispheric differences in schizophrenia asked subjects to listen to specific speech syllables (that were presented differently to each ear) while attending with either their left ear, right ear, or neither. Similarly, in Shine et al. (2014, 2209) subjects with Parkinson's disease were presented with a randomly assigned "monostable" and "bistable" monochromatic images and asked to identify the presence or absence of a bistable *percept* (i.e., perceiving two forms in the one picture, such as in the duck/rabbit figure, or not).

As these examples illustrate, the external-judgement tasks drew on different combinations of the inverse sets of characteristics than in the other types of tasks. However, the associations inherent in the inverse characterisation of mental imagery and hallucinations still contributed to the ways that each concept was used. Within Set-M there was a clear expectation that mental imagery is a necessary experience during tasks thought to mediate between perception and the cognitive functions of language and emotional judgement. Meanwhile, within Set-H these tasks drew on the view that the pathology of hallucinations stems from their misattribution to perceptual stimuli; a view that relies on the implicit characterisations taken to explain this confusion.

7.3.4 Resting-state Tasks

In resting-state tasks, subjects were asked to rest, relax, or otherwise lay still and awake during the extent of the fMRI scan. The resting-state task was uniquely suited to investigating the state of experiencing spontaneous SLMP. Within Set-M, only one investigation of spontaneous SLMP was reported; and it required abandoning some of the typical characterisations of mental imagery. In this study, Doucet et al. (2012, 3195) instructed subjects to "keep their eyes closed, to relax, to refrain from moving, to stay awake, and to let their thoughts come and go [during the fMRI scans]". In contrast to the usual focus on voluntary imagery, Doucet et al. (2012) specifically investigated the role of visual imagery in spontaneous, undirected, thoughts. This approach built on prior research that had identified visual imagery as a key experience during mind-wandering, and the subsequent suggestion that "the resting state is an extremely active state during which we pursue fundamental life tasks" (Doucet et al. 2012, 3194). Within this context, the typical characterisation of mental imagery as a volitionally-controlled experience was ignored so that the existence of spontaneous SLMP in healthy subjects could be investigated.

This flexible adaptation of the concept used for ordinary SLMP went unmarked – instead, the accepted use of the concept of mental imagery (to investigate ordinary forms of SLMP) was simply repurposed to investigate experiences of SLMP that did not fit the typical characterisation of this concept. Indeed, despite this adaptation, the specific phenomena being investigated (ordinary spontaneous SLMP) was not distinguished from other types of spontaneous SLMP beyond using of the concept of mental imagery. This can be seen in the experimental steps sometimes following fMRI scans. This step involved asking subjects to indicate the amount of time spent during the scan on either visual imagery or inner speech (Doucet et al. 2012, 3196). However, for this follow-up task, visual imagery was defined by the relatively obscure and circulatory phrase: "as having thoughts in the shape of images"

(Doucet et al. 2012, 3197). In addition, the concept of inner speech was defined broadly to include both "talking to oneself with one's own voice without overt production, as well as auditory mental imagery, which is associated with the recall of elements of conversations spoken by oneself or others" (Doucet et al. 2012, 3197). This comparison between visual imagery and inner language (whether image-based or not) positioned both visual and auditory SLMP as ordinary aspects of ordinary thought.

Within Set-H, the variable of interest was determined during the subject selection process rather than by the experiences of subjects during the resting-state task. Subjects were allocated to groups based on whether they had previously experienced hallucinations in a specific modality. Subjects in both groups were given the same resting-state instructions. For example, during the fMRI scan subjects were instructed to "close their eyes and try to 'clear their mind' but not fall asleep" (Vercammen et al. 2010, 913); to "simply rest in the scanner with their eyes closed and not fall asleep while remaining as still as possible" (Yao et al. 2014, 5661); or to remain "still in a state of wakeful rest with their eyes closed" (Amad et al. 2014, 185).

There was rarely any documented record that SLMP had occurred during these resting-state tasks. Even in those experiments that checked whether SLMP were experienced during the scan, the purpose was to either exclude acute experiences of hallucinations from the scanning data or to verify group differences. In the first case, a follow-up step identified those subjects that did experience hallucinatory experiences to exclude their results from the analysis. For example, Diederen et al. (2013, 1687) specifically reported that "Following acquisition of the resting-state scan, participants were asked if they had experienced hallucinations. Subjects experiencing AVH during scanning were excluded from analyses". This post-scan exclusion criteria was intended to improve on prior studies where the inconclusive results "could have been influenced [by the mere presence of hallucinations] as most studies did not exclude patients with active AVH, or did not report if AVH were present during scanning" (K. M. J. Diederen et al. 2013, 1686).

In the second case, the follow-up step was used to confirm group-differences rather than to verify the state of SLMP experiences during rest. For example, Sommer et al. (2012, 2) reported that "patients were asked whether or not they had experienced AVH during the resting-state scan. Likewise, healthy control subjects were asked for AVH, which were denied by all of them". Then, although acknowledging that only 63% of patients had experienced hallucinations during their scan, the results from all subjects were included in the analysis (Sommer et al. 2012, 3). The justification that Sommer et al., (2012, 3) provided for this methodological choice was that all of the test subjects had been selected based on their history of chronic hallucinations.

These examples from Set-H highlight that, while there was no surprise that hallucinations were experienced during a resting-state, there was also little interest in isolating these acute SLMP experiences for further analysis. Instead, even when subjects were considered capable of reporting on the presence/absence of their hallucinations, the state of experiencing SLMP was only of secondary interest. Instead, resting-state experimental tasks were intended to help identify dysfunction within test-subjects; a dysfunction that might explain their predisposition to hallucinate. This dysfunction was expected to be identifiable regardless of whether subjects were experiencing hallucinations at the time or not. In contrast, when a similar approach was taken within Set-M, there was a clear expectation that – even when spontaneous – mental imagery contributed to ordinary thought processes in a way that could be reported on by any individual self-reflecting on their experience of mind-wandering.

Comparing these resting-state examples from Set-M and Set-H demonstrates how expectations around the usefulness of mental imagery and the dysfunction of hallucination go beyond specific functions. On the one hand, the presence of mental imagery during resting-state scans was investigated due to the variability of mental-activity within ordinary subjects. Within this context, spontaneous non-goal oriented mental imagery was interesting because it was associated with an unknown aspect of ordinary resting-state cognition. Whereas, there was an expectation that comparing the resting-state scans of subjects with and without a history of hallucinations would be of more value than investigating the presence/absence of hallucinations during the resting state. While hallucinations experienced during a resting-state were expected, these were taken as a signifier of a general dysfunction that should be identifiable all the time rather than just during the hallucinatory state.

7.4 The Contributions of Conceptual Tools to Methodological Procedures

In this chapter I examined three methodological aspects of the fMRI experiments documented in Set-M and Set-H: the individuation of SLMP for further investigation; the articulation of experimental aims; and the experimental conditions during fMRI scans. In each of these, obliquely articulated mediator-view associations (about the interdependence of ordinary and pathological experiences of SLMP) can be seen to structure the uses of each concept (mental imagery or hallucinations).

As detailed in Chapter Four, mediator-view associations about SLMP provided the body of knowledge within which inverse characterisations of mental imagery and hallucinations explained why some SLMP are ordinary while other SLMP are pathological. The philosophical context for the mediator-view of SLMP was rejected in the twentieth-century; nonetheless, assumptions inherited via these distinguishing characteristics have been carried along by the concepts of mental imagery and hallucinations (as each is used for investigating ordinary and pathological experiences of SLMP respectively). These entrenched assumptions inadvertently contributed to the design and implementation of the methodological procedures reported for the fMRI experimental investigations into SLMP (as documented in

Set-M and Set-H). These contributions were highlighted in the earlier examples and can be summarised in three points.

Firstly, the distinction between ordinary and pathological SLMP was taken for granted: the concepts of mental imagery and hallucinations were routinely used without any introduction, explanation, or justification. Used in this way, functional and dysfunctional SLMP were investigated as experiences that can be readily individuated by using the concepts of mental imagery and hallucinations respectively. In addition to this distinction being taken for granted, typical characteristics were still relied upon (either explicitly or implicitly) to identify subjects that experience either mental imagery or hallucinations.

Secondly, the individuation of the SLMP of interest and the articulation of experimental aims combined to set the stage for the experimental conditions used to identify SLMP-neuroanatomical-correlates. These experimental conditions also relied implicitly on the typical characterisations of each concept. For example, within Set-M, subjects sometimes received specific instructions to use mental imagery; more often instructions assumed that the task required SLMP (and that the SLMP experiences would by voluntary and/or readily controllable). Meanwhile, within Set-H, subjects were rarely given detailed instructions. Instead, subjects were of interest simply because they reported experiences that conformed to one or more of the typical characteristics of hallucinations – such as, high-degrees of perceptual similarity, lack of control, external location, and subjective reality.

Thirdly, in both article sets, the data generated from similar experimental conditions also relied upon mediator-view assumptions that ordinary SLMP and dysfunctional SLMP are distinct phenomena that should be investigated independently of each other. For example, the relevance of any SLMP-neuroanatomical-correlates identified by the SLMP-presence tasks were framed differently in Set-M and Set-H. If the SLMP-presence-task was thought to rely on mental imagery (assumed to be experienced as merely resembling perception) any resulting data was expected to help identify how ordinary SLMP contributed to neurocognitive function. Conversely, if the SLMP-presence-task was undertaken by subjects with a history of hallucinations any resulting data was expected to help identify the dysfunctional neurocognitive processes predisposing individuals to compellingly real SLMP experiences. In such cases, it was expected that the dysfunction explaining the predisposition to experience types of SLMP would be present as an abnormality of the individual (rather than just during hallucinatory experiences).

Compared in these ways, each of the concepts used for investigating SLMP can be seen to set the standards for the experimental conditions intended to isolate the aspect of SLMP of interest; standards that directed research towards a specific goal. Even when similar experimental conditions were employed by articles in both Set-M and Set-H, the specifics of these conditions differed: subjects were given different instructions based on the expectations of the data generated by these conditions. In each case, these differences aligned with the broader goals of each concept. Used as independent tools structured for investigating these different epistemic goals, the concepts of mental imagery and hallucinations each set the standards for the methodological procedures documented to have met the aim articulated in each article.

This highlights how, even though the concepts were used to individuate different experiences of SLMP, each also carried their shared sets of interdependent associations into experiments that generated similar SLMP-neuroanatomical-correlates. In doing so, a critical point of context emerges for the argument presented in Chapter Six. In that earlier chapter I demonstrated that similar experimental findings (SLMP-neuroanatomical-correlates) can generate divergent knowledge-claims (about the function/dysfunction of SLMP) depending on how the type of phenomena investigated (SLMP) were conceptualised (as either mental imagery or hallucinations). In relation to this, I argued that the structured uses of these two concepts framed the material agency for the purposes of abstraction into forms of theoretical and factual knowledge. Positioned within the present context, these structured uses can also be seen to provide the reference point for generating the data upon which these knowledge-claims depend; not just for framing the interpretation of this data. In each case, the concept was used as a taken-for-granted tool for investigating either ordinary or dysfunctional SLMP. These uses relied upon the assumption that these two types of SLMP are readily distinguishable from each other (based on one or more of their typical characteristics).

Comparing these experimental practices highlights that the concepts of mental imagery and hallucinations each played key roles in the experimental practices documented in Set-M and Set-H. This included operating as tools to individuate the type of SLMP investigated; helping to articulate experimental aims; and providing the background knowledge within which methodological choices were made when designing the experimental conditions for isolating SLMP-neuroanatomical-correlates. Furthermore, the uses of these two concepts were each structured by entrenched mediator-view associations about SLMP. Used in this way, the concepts of mental imagery and hallucinations provided the conditions within which choices could be made when designing experimental conditions. These conditions include the entrenched mediator-view associations that structure the uses of these two concepts throughout the (documented) methodological steps of fMRI experiments; not just in packaging experimental findings for theoretical consumption.

As the three earlier points illustrate, even though the interdependence of these concepts was not recognised, the entrenched series of associations were routinely drawn upon to underwrite a range of methodological choices. Given this, the divergence of knowledge-claims from similar SLMP-neuroanatomical-correlates (detailed in Chapter Six) cannot be explained as simply differing interpretations of experimental data. Instead, the structured uses of the concepts of mental imagery and hallucinations also contributed to the design and implementation of the experiments that generated the data in the first place. I will clarify this point in the next chapter. In this chapter I have simply aimed to demonstrate that the concepts of mental imagery and hallucinations contributed to the design and methodological choices reported for experiments investigating SLMP as ordinary or dysfunctional neurocognitive processes respectively.

8 Using Mental Imagery or Hallucinations Concepts in Experiments

In focusing on the *structured uses* of scientific concepts, I have examined the possibility that two specific concepts – mental imagery and hallucinations – each operate as structured tools that can actively contribute to the knowledge generated about SLMP in neuroimaging experiments. To this end, I have asked a sequence of questions. I began in Chapter One by drawing on scholarship within historical, philosophical, and social studies of scientific practice, to highlight a convergence between accounts that focus on either the *material* or *conceptual* contributions to experiments. Building on these foundations in Chapter Two, I developed the proposal that the structured uses of concepts can contribute to experimentally generated knowledges; contributions that may be analogous to the active contributions of material instruments. To illustrate and further examine this proposal I compared how the concepts of mental imagery and hallucinations are each used to investigate SLMP in neuroimaging experiments. Firstly, in Chapter Three I explored the current independent uses of these two concepts for individuating distinct types of SLMP. In Chapter Four I asked how the current independent uses of mental imagery and hallucinations can be understood in relation to their intersecting historical development for individuating distinct types of SLMP. With this historical context in mind, I then sought to compare the uses of the concepts of mental imagery and hallucinations in a sample of documented fMRI experiments (Chapters Five to Seven).

This sequence of questions provided valuable structure for my research. However, the connections between each research stage requires additional consideration. In this chapter I review and clarify the over-arching argument that each of the earlier elements of my research supports. In its briefest form, this argument is that the concepts of mental imagery and hallucinations operate as structured tools that actively contribute to the knowledge generated by neuroimaging experiments. The support I have offered for this argument can be clarified by articulating a series of claims:

i. That the concepts of mental imagery and hallucinations are each *used as tools* in neuroimaging experiments;

ii. That, as experimental tools, the concepts of mental imagery and hallucinations are each *used for* investigating discrete epistemic goals;

iii. That implicit interdependent associations *structure* the uses of the concepts of mental imagery and hallucinations as experimental tools for independently investigating these discrete epistemic goals;

iv. That it is through these *structured uses* that the concepts of mental imagery and hallucinations actively contribute to the knowledge generated in neuroimaging experiments;

v. And, that the contributions of the structured uses of these concepts (as tools for investigating discrete epistemic goals) can be considered analogous, yet not equivalent, to the *active* contributions of material instruments within experiments.

The connections between these five claims are far messier than listing them as a cumulative series suggests. However, while recognising other possibilities, this series provides a logical progression with which to clarify the connections between the various research questions I investigated. Therefore, after reiterating the foundational propositions upon which I am building, this chapter will detail each of these claims in turn. Finally, in presenting this concrete and context-specific argument I will return to support the more abstract proposal introduced in Chapter Two: that there is value in investigating the possibility that, like material instruments, the structured uses of concepts can actively contribute to the dynamics of experimental practice.

8.1 Clarifying the Analytic Foundations

There are two propositions that underpin my analysis of the uses of the concepts of mental imagery and hallucinations in neuroimaging experiments. I justified the first of these in Chapter Three: mental imagery and hallucinations are both used as concepts for individuating types of SLMP for investigation in neuroimaging experiments. The second proposition is that mental imagery and hallucinations are used as *stable* concepts in neuroimaging experiments. As detailed in Chapters Three and Five, this stability is evident in the routine independence of each concept from the other: each concept is frequently used without any reference to the other concepts; and, even when used in the same context, the distinction between the two is taken for granted.

As a starting point for further analysis, in Chapter One I outlined a selection of views about scientific practice that I adopted based on three complementary themes that emerge across a range of historical, philosophical, and social studies of scientific practices. The first of these themes highlights a view of scientific practice as generating knowledge that is simultaneously contingent on the conditions of production and able to provide objective accounts of the real world. The second theme positions material instruments as actively contributing to the generation of scientific knowledges. The third theme can be seen in the view that scientific concepts can be used in experimental practices in ways that extend beyond their roles as merely mental or linguistic representations.

In addition to these three starting points, my argument also rests on several specific propositions I adopt from specific strands within historical, philosophical, and sociological studies of scientific practices (detailed in Chapter Two). The first strand focuses on the uses of concepts as tools in experimental practices (Boon 2015b, 74; U. Feest 2012, 176–79; MacLeod 2012, 69; Steinle 2012, 106). Following Feest (2010, 180–82), I define tools as devices that, whether physical or not, intervene in the study of an object or type of phenomena (in ways that generate data about the object/phenomena). I also drew on Pickering's (1995b, 158–59) description of tools as human-machine couples that, like machines more generally, have agency that can resist human intentions (in ways that contribute to the generation of scientific knowledge about that object/phenomena).

Building on these starting points, in Chapter Two I argued that there were valuable parallels between Feest's analogy between instrument-use and concept-use (where each operate as tools that intervene in experimental practice) and Pickering's analogy between material instruments and conceptual structures (where each embody nonhuman agency in a way that can resist human intention). For the present purposes, there are two points to emphasise: firstly, that the concepts of mental imagery and hallucinations can each be understood as tools that are used in neuroimaging experiments; and, secondly, that the uses of these tools involve dynamic human/nonhuman couplings that intervene in the study of SLMP (and thereby generate data that resists the agency of human intention within scientific practice).[190]

Another proposition underlying my argument relates to the obvious omission in the discussion above: if concepts are tools, then what are these tools used for? In answer to this question, I have built upon the view that concepts are used *for* investigating specific epistemic goals within experimental practices. As such, I have explored how the uses of two ambiguously delineated concepts are each used independently of each other for investigating the discrete epistemic goals of explaining either functional or dysfunctional experiences of SLMP. By taking this approach it should be clear that I am primarily interested in just *one* of the types of work that concepts do when used as tools for in investigating specific goals. This

[190] In this context, the intentions of human actors are taken to be articulated by the aims reported in the published accounts of their experiments; the intentions of scientists as individual actors are beyond the present scope.

type of work that a concept does, or allows to be done, can be described as a concept's epistemic function (Steinle 2012, 107).[191] With this in mind, the usefulness of a concept can be analysed in terms of the epistemic function that it plays in research activity aimed towards a specific goal.

I drew on several approaches in exploring this notion of goal-directed concept uses, focusing most on Brigandt's (2012, 99) argument that, in addition to their more commonly recognised inferential and referential components, concept-use involves another component: the epistemic goal that a concept is used for. For Brigandt (2010, 23) there are some specific uses of concepts where the rationale for use – or inferential role – is tied to the pursuit of a specific set of epistemic goals within a given scientific community. Furthermore, as Brigandt (2012, 78) argues, when a concept is used in this way, it embodies the conceptual relationships that support the referential use of that concept. Drawing on the obvious parallels with Pickering's account of conceptual structures, I suggested that there are structured associations inherent in the inferential components of concepts; that these associations embody conceptual relationships; and that – in doing so – the structured associations (embodied by the concept) provide the rationale for using that concept to pursue specific epistemic goals. This point comes into focus when considering how the concepts of mental imagery and hallucinations are used independently of each other for pursuing discrete epistemic goals – to identify the SLMP-neuroanatomical-correlates for the purposes of investigating either functional or dysfunctional neurocognitive processes respectively – despite each depending on an interdependent series of associations.

This brings me to the remaining series of theoretical propositions underlying my argument. Specifically, that the uses of concepts (as tools for investigating specific epistemic

[191] As discussed in Chapter Two, these functions are in addition to the non-epistemic roles concepts can play in science.

goals) are *structured*; that the structured uses of concepts operate in ways that can resist the intentions of humans; that this resistance is one of the ways in which conceptual tools intervene in experimental methodology; and that, by intervening in experiments, the structured uses of concepts can contribute to the knowledge generated in these practices. Once again, this series of propositions has been drawn from several sources. Most directly, I have adopted an interest in the structured elements of conceptual practice from Pickering's notion of conceptual structures (examined in Chapter Two). As part of this, I explored his notion that the alignment between material performances and conceptual structures contributes to the stabilisation of contingent knowledges such that they articulate reliable objective accounts of the real world (Pickering 2015, 126–27). In addition, I positioned Pickering's approach as intersecting with insights from *HPS* about the structured elements of conceptual practice – particularly those tying the interest in the *structured* uses of concepts with their uses *for* specific purposes. As part of this, I drew on work emphasising that the functional roles of concepts need to be understood in relation to their histories (including: Bachelard 1989; Brigandt 2012; MacLeod 2012; Rheinberger 2011; Steinle 2010a).

Drawing these approaches together, historically contingent parcels of sedimented information can be understood to structure the fields of knowledge within which a concept is used to pursue a specific epistemic goal. Put another way, the historically situated usefulness of a concept builds up around the uses of that concept for investigating associated epistemic goals. These concepts can then be used without any explicit awareness of the structured fields of knowledge within which these functions emerged. By examining how the uses of specific concepts are *structured* for pursuing specific epistemic goals it is possible to draw attention to the inadvertent contributions that these concepts make to the dynamics of localised scientific practices. Within this context, my focus is on illustrating how implicit associations can continue to be embodied by the uses of concepts for the pursuit of certain goals even after the justification for these associations have been abandoned.

8.2 The Uses of Concepts as Tools in Individual Experiments

The first claim in my series is that the concepts of mental imagery and hallucinations can operate as tools in neuroimaging experiments. Building on a specific understanding of experimental tools, discussed above, the principal support for this claim can be found in the way that each of these concepts intervened in a range of methods documented for the neuroimaging experiments analysed in Chapters Six and Seven. To clarify how these two concepts each intervened in these neuroimaging experiments I will briefly revisit some of the general trends in my earlier analysis.

The first point of intervention discussed was the roles that the concepts of mental imagery and hallucinations each played in the interpretation of similar experimental findings; interpretations that supported diverging knowledge-claims. Firstly, the similar experimental findings consisted of SLMP-neuroanatomical-correlates. That is, the correlations identified between localised changes in neural activity and experiences conceptualised as either mental imagery or hallucinations (depending on the experiment). Secondly, depending on the concept used in these experiments, these similar findings were proposed to support knowledge-claims about the role of SLMP in either functional or dysfunctional neurocognitive processes.

This way of using conceptual tools can be illustrated by revisiting one of the examples from Chapter Six. On the one hand, an experimental finding that an increase in STG activity correlated with SLMP in Set-M contributed to proposals that there are modality-specific neurophysiological processes underlying mental imagery. At the same time, when correlations between an increase in STG activity and SLMP were reported in Set-H this finding contributed to proposals that dysfunction within the auditory perception of speech might explain the abnormal language-processes that produce hallucinations. Based on these types of comparisons, I argued that when equivalent SLMP-neuroanatomical-correlates were reported by experiments using the concepts of either mental imagery or hallucinations, these similar experimental findings contributed to disconnected first-order knowledge-claims.

Similar SLMP-neuroanatomical-correlates were therefore taken to support diverging knowledge-claims; claims that aligned with the entrenched associations embodied by the concept used for the SLMP investigated (mental imagery or hallucinations). This difference in alignment was consistent regardless of which arrangement of other variables were included in the experimental practices (such as the experimental conditions, the theoretical context, and so forth). To put this in Pickering's terminology, material agency captured by the fMRI machines (such as an unexpected measurement of localised neural activity) was framed through an alignment with a given conceptual structure (either the concept of mental imagery as used to investigate neurophysiological function, or the concept of hallucinations as used to investigate neurophysiological dysfunction) for the purposes of articulating knowledge-claims that contribute to specific epistemic goals (explaining the neurocognitive functions of mental imagery, or the dysfunctional neurocognition responsible for hallucinations).

However, while mediating between the material findings and the abstract theoretical explanations was important, this articulation was just one aspect of a more entrenched process of alignment between the experimental methods and the concepts used within these practices. This highlights that the concepts of mental imagery and hallucinations can each be understood to have multiple functions. Most obviously, each concept operated to individuate a specific type of SLMP for further investigation. In addition, each functioned as a data-generating tool: both to measure whether the SLMP of interest was present and for exploring the very nature of SLMP experiences.[192]

As the comparative analysis offered earlier highlights, each knowledge-claim depended upon the existing conceptualisation used to individuate the SLMP experiences that the experiment was designed to investigate. Another way to articulate this is to borrow Feest's terminology. Empirical presuppositions specified the paradigmatic conditions for the application of each concept; these presuppositions allowed these tools to be used to intervene in the domain of study – an intervention that generated data about the very nature of the type of phenomena of interest. Therefore, rather than simple representations of the relationship between how the measurements of neural activity correlated with experiences of SLMP, these concepts were used in ways that generated experimental data. That is, despite being vague conceptualisations of the phenomena being investigated, these conceptual tools helped to generate data by providing one of the conditions within which the measurement of SLMP-neuroanatomical-correlates could be undertaken. This data provided the basis for published knowledge-claims.[193]

Building on this understanding, I suggested that these diverging knowledge-claims pivoted on a key variable within the heterogeneous interactions contributing to these experiments: the conceptualisation of the type of SLMP experience being investigated. More specifically, I proposed that the concepts of mental imagery and hallucinations each played an active role in resisting intentional human agency *prior* to framing the knowledge-claims generated by experimental findings. I illustrated (with multiple examples in Chapter Seven)

[192] See Feest (2010, 182) for more detail on the distinctions between different types epistemic functions of conceptual tools.

[193] To be clear, regardless of whether these experiments contributed to *robust* knowledge, or whether the concepts of mental imagery and hallucinations *should* be used, experiments using these concepts *in practice* were published in support of specific knowledge-claims.

the intervention of these concepts in experiments. For example, my comparison of the articles in Set-M and Set-H demonstrated that a specific conceptualisation of SLMP (as either mental imagery or hallucinations) operated as a key element in the motivation and design for individual experiments.

These conceptual contributions typically went unacknowledged. Firstly, when it came to experimental aims, there were clear differences in the expected relationship between the experiences of SLMP investigated and other neurocognitive processes. These differing expectations depended on whether the concept used was mental imagery or hallucinations – even when controlling for other variables (including the degree of theory-independence of the concepts used). Expectations such as these were carried along with the concept used for the SLMP investigated. For example, if the aim was to investigate the relationship between SLMP and perception carried predictably differing expectations as to the relationship between SLMP and perception. Experiments using the concept of mental imagery assumed that these SLMP were necessarily functioning alongside perception. Whereas the expectation in experiments using the concept of hallucinations was that these SLMP indicated dysfunctional perception. In each case, the uses of these concepts presupposed how the type of SLMP to be investigated related to perception. These presuppositions contributed to the dynamics of the experiment by providing the conditions within which specific (yet routine) methodological choices could be made.

Conceptual interventions in experimental practice were further illustrated by comparing different methodological approaches to verifying that subjects had indeed experienced the type of SLMP being investigated. For example, in those experiments documented in article Set-M, experimental tasks were often assumed to require their subjects to experience mental imagery – no verification step was reported. Furthermore, even on those occasions when experiences of mental imagery were subsequently verified by self-reports, the assumption that all healthy subjects rely on mental imagery was still evident. In such cases, the presence of SLMP was taken for granted and the verification process focused on whether subjects were aware of certain characteristics (such as vividness).

Whereas, in those experiments documented in Set-H, there was often a much earlier step included for verifying that the subjects selected had, in recent history, experienced SLMP that could be conceptualised as hallucinations. With this step in-place, few articles reported verifying whether subjects experienced hallucinations during an fMRI scan. Even those that did include a verification step considered it to be either a limiting aspect of the design or a lesser part of the overall experiment. This hesitancy can be understood within the general disregard for including steps intended to verify the presence of the state of experiencing hallucinations. This distain for investigating the hallucinatory state was considered justified without a need for explanation: an approach aligning neatly with the widely-held view that clinical subjects could not be trusted to recognise their hallucinatory experiences or judge them as distinct from external perception. Recall from Chapter Five that, while hallucinations can contribute to confusion between perception and reality, this is by no means a definitional characteristic. Given this, the untrustworthiness of hallucinating subjects can be better understood in relation to the entrenched associations carried along by the concept of hallucinations as indicating an individual failing of judgement/reason.

As these examples reiterate, it was not simply that the concepts of mental imagery and hallucinations were each taken to refer to a distinct experience of SLMP within these experimental conditions. Instead, to borrow Brigandt's (2010, 2012) terminology this time, a range of conceptual relationships provided the foundations for the inferential role of each concept. Each concept was used as the embodiment of the series of associations. These associations supported the concept's referential role within experimental conditions that were set in relation to specific epistemic goals.

Therefore, in addition to each concept representing a type of SLMP (in a way that was thought to reliably individuate distinct experiences of SLMP that can be meaningfully investigated), the concepts of mental imagery and hallucinations each had an inferential component that allowed it to be used in ways embodying specific conceptual relationships that contributed in active ways to the experimental methodology. On the one hand, it was taken for granted that any, and all, healthy subjects would experience ordinary SLMP (conceptualised as mental imagery) in a standard way. On the other hand, it was taken for granted that all subjects reporting clinically relevant experiences of SLMP (conceptualised as hallucinations) would have difficulty recognising and judging these experiences as distinct from perceptual stimuli.

These assumptions sit at odds with the historical development of these two concepts (examined in Chapter Four). Firstly, the conceptual relationship between mental imagery and ordinary thought processes has a long – and heavily disputed – history. Likewise, there have also been numerous unresolved debates over the conceptual relationship between hallucinations and an individual failure to adequately regulate internal thought processes. Yet, despite the unresolved problems with these associations, each concept continued to embody the interdependent positions of these associations within the entrenched conceptual relationships that structure the independent uses of each concept. In the example just provided, these entrenched associations are evident in how researchers assessed whether a given subject would be able to generate and/or appropriately judge an experience of SLMP (conceptualised as either mental imagery or hallucinations). More generally, routine associations embodied in each concept provided a limited field of possibilities within which the correlation between SLMP and changes in neural activity could be measured. I will return to this point later.

For now, my main point is that the concepts of mental imagery and hallucinations were both used as *tools* in neuroimaging experiments. That is, more than merely representing the type of phenomena to be investigated, these concepts were used in ways that drew on unquestioned associations about these phenomena; associations that contributed to the methodological choices of individual experiments. Furthermore, these concepts were not only relied upon to articulate the hypothesis and interpret the results of these experiments. Rather, the uses of these concepts intervened to provide the very conditions within which the material instruments generated their results.

8.3 The Uses of Concepts as Tools to Pursue Epistemic Goals

The second claim in my argument is that, as tools, the concepts of mental imagery and hallucinations are used in neuroimaging experiments to investigate discrete epistemic goals. As earlier, this claim can be supported most simply by pointing out – as I did in Chapters Three and Four – that the concept of mental imagery is used with the goal of investigating the various functions of SLMP, while the hallucinations concept is used with the goal of investigating the dysfunction of SLMP experiences. However, my support for this claim also draws on a comparative analysis of how the functions of each concept were tied to their uses for pursuing different epistemic goals in the published neuroimaging experiments analysed. In these experiments, the concepts of mental imagery and hallucinations were clearly tied to the two distinct goals outlined above.

Firstly, using the concept of mental imagery for investigating SLMP-neuroanatomical-correlates was always tied to the broader goal of understanding the role of ordinary experiences of SLMP in neurocognition (that could sometimes go awry). Specifically, the concept of mental imagery was almost always used for pursuing the goal of identifying SLMP-neuroanatomical-correlates as these relate to functional neurocognition. Furthermore, even in the one experiment that investigated the role of mental imagery in abnormal neurocognitive processes, it was of interest in relation to the assumption that imagery is required to solve specific types of language comprehension tasks.[194] Secondly, the concept of hallucinations was always used with the goal of investigating how SLMP-neuroanatomical-correlates were relevant to dysfunctional neurocognitive processes. In relation to this goal, a range of ordinary neurocognitive processes were of interest as candidates for these disruptive processes – with ordinary SLMP of less interest than other cognitive functions such as language and sensory processing.

The divergence of these goals relies on the assumption that it is possible to identify specific SLMP-neuroanatomical-correlates for the discrete experiences of either ordinary mental imagery or pathological hallucinations. At this point, it is important to note that these epistemic goals are broader than the experimental aims documented within the two principle sets of articles that I collected (Set-M and Set-H). Experimental aims report specific articulated intentions of the experiment, or set of experiments, being documented (for example, testing a hypothesis or exploring the value of a new technical approach). These aims contribute to the broader epistemic goals with which each concept is used within the neuroimaging research community. For example, it is only in relation to specific epistemic goals (investigating the neurocognitive functional or dysfunctional roles of SLMP in neurocognitive processes) that the concepts of mental imagery and hallucinations were useful (for individuating ordinary or pathological experiences of SLMP) in neuroimaging experiments. In other words, two discrete epistemic goals were evident in the types of assumptions about what needs to be explained when using the concepts of mental imagery and hallucinations respectively.

[194] See the earlier discussions of the experiment documented by Kana et al. (2006).

I will return to the role of assumptions in structuring epistemic goals in a moment. First, it is worth revisiting examples from the articles in Set-M and Set-H to help to clarify how this distinction between experimental aims and epistemic goals plays out in each context. As before, I will start with Set-M. A common aim for neuroimaging experiments in Set- was to understand the role of mental imagery in memory. For example, the aim of the experiment documented by Slotnick et al. (2012, 14) was to identify how a specific neuroanatomical correlate of visual mental imagery compared to that of visual memory. In addition, Slotnick et al. (2012), positioned their findings as answering a question at the juncture of two streams within the neuroimaging literature – one on memory and one on imagery. Positioned in this way, the aim of the individual experiments is directed at a broader epistemic goal shared within neuroimaging research community; identifying the neuroanatomical correlates of ordinary neurocognitive functions (in this case, memory and imagery). Therefore, the aim of identifying the neuroanatomical correlates of ordinary mental imagery was targeted towards the epistemic goal of contributing to knowledge about the role of these ordinary experiences of SLMP in other functional neurocognitive processes (such as memory).

As with this example, experimental aims documented in the articles from Set-M were always positioned within the context of the broader epistemic goal of identifying the neuroanatomical correlates of ordinary neurocognitive functions. Meanwhile, the experimental aims documented in the articles from Set-H were all positioned as contributing to a different epistemic goal: identifying the dysfunctional neurocognition that cause symptoms of mental disorder. For example, van de Ven et al.(2005, 647) stated that their aim was to compare changes in neural activity in the auditory cortex during experiences of either hallucinations or auditory perception via a novel data-driven analysis. This aim echoes those of numerous prior experiments comparing the neural correlates of hallucinations and perception: the point of novelty in the experiment was the data-driven methodology. This method was presented to demonstrate a way of investigating the neuroanatomical correlates of the state of hallucinating without relying on the unreliable self-reports of clinical subjects. In this way, the aim of the experiment was consistent with a broader goal within the neuroimaging research community. This goal centred on the use of neuroimaging techniques to identify the SLMP-neuroanatomical-correlates relevant to dysfunctional neurocognitive processes.

While only revising two examples here, this distinction is also supported by the earlier comparative analysis of published research. Within the context of neuroimaging experiments, the concepts of mental imagery and hallucinations were each used to articulate a wide range of experimental aims that always contributed, in turn, to diverging epistemic goals (focusing on investigating SLMP-neuroanatomical-correlates that were relevant to neurocognitive function or dysfunction respectively).

These epistemic goals were pursued within the overlapping interdisciplinary contexts that each contributed to broader contexts within the neuroimaging research community. Therefore, while these two epistemic goals were typically pursued independently of each other, both cut across the semi-permeable disciplinary boundaries within this broader research community. For example, the differing epistemic goals pursued in the articles from the Set-M and Set-H were consistent across the multiple disciplinary affiliations of authors, overlapping publication contexts, and in relation to a wide range of theoretical and methodological questions. As such, the epistemic goal can be understood as a component of the concept as it is used within a given context – in this case within research that coalesces around a given experimental technique – rather than as tied to the dynamics of the theoretical context of a given discipline.

This point highlights the value of investigating the smaller units within experimental systems without getting distracted by the question of the boundaries between disciplines that experimental research frequently cross.[195] Given this, another question emerges. How is it that these concepts came to embody diverging epistemic goals in a way that could actively contribute to the knowledge generated in these interdisciplinary experimental practices? This brings the discussion back to the interdependent histories within which these two epistemic goals diverged; an interdependence that is often forgotten despite each of these goals being pursued within the interdisciplinary context of neuroimaging experimentation. In relation to this, I argued in Chapter Four that the current uses of the concepts of mental imagery and hallucinations in neuroimaging experiments need to be understood in relation to the how these two concepts came to be used independently from each other for explaining why SLMP are experienced as either functional or dysfunctional elements of neurocognitive processes.

To appreciate these historical contexts, it is worth revisiting some of the ways in which the uses of the concepts of mental imagery and hallucinations intersected on the path to their current uses as independent tools in neuroimaging experiments. Firstly, during the nineteenth century, scientific interest in the concepts of mental imagery and hallucinations overlapped considerably. On the one hand, nineteenth-century investigations into experiences of mental imagery explored questions about the individual variability of such experiences – often including descriptions of experiences of SLMP with characteristics later considered typical for experiences conceptualised as hallucinations. At the same time, one of the principle nineteenth-century debates about the concept of hallucinations was over what characterised the experiences of SLMP individuated by that very concept. A customary justification for the various characteristics proposed was their value in explaining the difference between pathological hallucinations and those ordinary experiences of SLMP associated with the more established concept of mental imagery. However, despite questions at the heart of these

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[195] See Appendix 1 (Annotated Glossary) for my arguments in Chapter Two about *disciplinary agency* relate to the notion of experimental systems (Rheinberger 1994, 2011; Rouse 1996, 2011a).

interdependent histories remaining unresolved, the twentieth century saw these two concepts increasingly used independently of each other for pursuing discrete epistemic goals. The concept of mental imagery came to be used to pursue the goal of explaining aspects of functional neurocognition. Meanwhile, the concept of hallucinations came to be used to pursue the goal of identifying the dysfunctional neurocognition that cause pathological states of mind.

Of course, to be used independently for the pursuit of these two discrete goals, a lot of work went into justifying that the types of SLMP conceptualised as mental imagery and hallucinations were discrete experiences (see Chapter Four). A reoccurring theme during this process can be seen in the various proposals for typical characteristics intended to reliably differentiate between functional and dysfunctional types of SLMP. Recalling Table 5, these characteristics can be understood as a way of explaining the conceptual distinction between ordinary and pathological experiences of SLMP within the context of nineteenth-century mediator-views of SLMP. Within this context, mental imagery was positioned as a mediator between sensations and abstract thought; a mediator that, if dysfunctional, could threaten the ability to form reasonable judgements about the world. However, even after this philosophical view of SLMP was abandoned during the twentieth century, these early characterisations have continued to feature in the uses of each concept (see Chapters Three and Seven).

To simplify the story presented in Chapter Four considerably, a set of typical characterisations of each concept became routine during the late twentieth century. Along the way, questions over the unresolved relationship between the characteristics considered typical of each concept were abandoned. Instead, the shifting layers of conceptual associations within which these inverse characterisations of ordinary and pathological experiences of SLMP emerged, began to settle within the inferential role of the concept. I will return to these associations in the next section. For now, the point to emphasise is that it became rare to examine – or even acknowledge – the difficulty of distinguishing between ordinary and pathological experiences of SLMP based on phenomenological characteristics. Instead, unresolved ambiguities as to the relationship between the concepts of mental imagery and hallucinations were obscured by two sets of characterisations – increasingly used independently of each other. That is, while these characteristics only make sense as the inverse sets that emerged within mediator-views of SLMP, they came to be used as independent criteria for individuating presumably discrete experiences of SLMP within neuroimaging experiments investigating functional and dysfunctional neurocognitive processes respectively.

Used independently of each other, the inverse characterisations of desirable and undesirable experiences of SLMP came to provide a flexible way of justifying the uses of the concepts of either mental imagery or hallucinations for investigating ordinary and pathological experiences of SLMP respectively. Indeed, as seen in Chapter Seven, these typical characteristics continue to operate in routine and unexamined ways within neuroimaging experiments. In addition to the examples above, this includes the role of typical characteristics during subject selection practices and the design of experimental conditions. This is exemplified by the roles that typical characteristics of mental imagery played within the experimental conditions documented in Set-M. Meanwhile, the typical characteristics of hallucinations featured heavily in the selection of subjects for the experiments documented within Set-H.

These inverse characteristics of mental imagery and hallucinations also contribute to the individuation of the type of SLMP experience of interest within neuroimaging experiments that use these concepts. As argued in Chapter Seven, a routine reliance on those characteristics implicitly associated with each concept structure the uses of each in ways that support the pursuit of a specific goal. In this way, and despite their historical interdependence, the types of SLMP conceptualised as either mental imagery or hallucinations came to be investigated as discrete experiences that were of scientific interest for largely unrelated goals.

Put simply, the difference I am emphasising here is that the various aims that these two concepts are used to articulate always target two different epistemic goals within the broader neuroimaging community. The concept of mental imagery is used for investigating the various functions of SLMP with the goal of contributing attempts to identify the neuroanatomical correlates of various elements of neurocognition. The concept of hallucinations is used for investigating dysfunctional experiences of SLMP with the goal of contributing to attempts to identify the neuroanatomical correlates of various elements of dysfunctional neurocognition. In the next section I will focus on the disciplined routines within which the nominally abandoned interdependent conceptual associations are nonetheless carried along by the independent uses of the concept of mental imagery and hallucinations for pursuing different epistemic goals.

8.4 The Structured Associations Embodied in the Uses of Each Concept

This brings the discussion to the third claim: that there is a shared series of routine conceptual associations that structure the uses of the concepts of mental imagery and hallucinations as tools for independently investigating these discrete epistemic goals within neuroimaging experiments. As discussed in Chapter Two, there are a range of approaches to analysing scientific knowledge that emphasise the *structured* elements of conceptual practice. Many of these have also emphasised that the epistemic roles of concepts need to be understood within the foundational parcels of information that structure the fields of knowledge within which the uses of a concept for pursuing specific epistemic goals are specified. An example of this type of approach is Steinle's (2010a, 213) description of the result of the sedimentation of concepts as like a coral reef – where the living and dead coexist. In Chapter Two I mentioned this analogy when exploring how Steinle's notion of sedimented conceptual-associations intersect with Pickering's description of conceptual structures. I return to it now to extend and adapt this metaphor to highlight the dynamic yet structured ways in which concepts are used in experimental practice.

To this end, Steinle's metaphor provides a way of highlighting how the current and sedimented components of concepts co-exist – with neither directing the processes of their dynamic relationship. However, in attempting to extend this metaphor it becomes clear that there are additional elements to conceptual practice that the grounded immobility of coral reefs might obscure. It is here that Pickering's approach – by bridging *HPS* accounts of concept-use and *STS* accounts of material agency – provides a way forward. I will return to this extension later. For now, the metaphor of a coral reef provides a narrative-arc within which to draw together some of the various approaches describing the structured uses of concepts in experimental practice that I explored in Chapter Two.

To begin with I want to focus on the notion that, like coral reefs, conceptual tools carry dead (implicit yet unarticulated) components that are vitally important for structuring the conditions of possibility within which the living (intentional) components of concept-uses emerge (and which shape, in turn, the momentary form within which each layer of the dead components settle as sediment). This focus also highlights how the historically situated usefulness of concepts can build up until the concept is able to be used for investigating stable epistemic goals without any explicit awareness of the structured fields of knowledge within which these functions emerged. In this way, the coral reef metaphor provides a valuable reminder that understanding the current uses of concepts requires an understanding of the history of disciplined associations that structure their routine uses for pursuing specific epistemic goals.

In relation to this, in Chapter Two I argued that examining the historical context for current dynamic interactions provides a way to identify the bodies of knowledge that provide the sedimented associations within which certain characteristic became routinely accepted attributes of specific concepts. Indeed, in my view, it is by examining the uses of concepts as *structured* by previously sedimented associations for pursuing specific epistemic goals that it becomes possible to glimpse how these routine performances continue – even after the justification for these entrenched associations has died – to structure the uses of concepts as experimental tools.

To clarify this argument, it is worth once again revisiting some of the key points gleaned from exploring the intersecting points within the histories of the concepts of mental imagery and hallucinations (detailed in Chapter Four). As summarised in Table 6, there were repeated unsuccessful attempts at determining how to reliably delineate between experiences of SLMP that were ordinary (conceptualised as mental imagery), abnormal (variously conceptualised), and pathological (conceptualised as hallucinations) throughout the nineteenth and twentieth centuries.

Each of these characteristic distinctions drew upon the same series of associations: the more forceful or vivid an image, the more difficult it is to control; an inability to control imagery is, in turn, indicative of a lack of self-regulation; while a failure to self-regulate can be attributed to a failure to make reasoned judgements about the source of an internally generated experience. Within this field of knowledge, these characteristics therefore helped to explain how a critical element of thought (mental imagery) could be experienced in such a way that it threatened an individual's ability to adequately judge their inner thoughts as distinct from real perceptions (hallucinations). As such, the inverse characterisation of mental imagery (as ordinary) and hallucinations (as pathological) made sense within the mediator-view of SLMP. It was this view of SLMP that provided the knowledge context for these inverse characterisations during the nineteenth century.

This series of associations provided an initial way of explaining differences between observed experiences of desirable and undesirable experiences of SLMP that were consistent with the available knowledge context. Put simply, the entrenched series of associations alludes to the way that the inverse characterisations of mental imagery and hallucinations provide proxy criteria for determining whether an experience of SLMP can be appropriately regulated by abstract reason (see Table 5). However, debates arose over the reliability of these inverse characterisations in delineating between ordinary and pathological SLMP *in practice*.

These debates were never resolved. Instead, the mediator-view of SLMP was simply discarded during the early twentieth century. Along the way, each concept came to be used independently of the other, often in contrast to some other intermediate concept of SLMP such as eidetic imagery or pseudohallucinations. These intermediate categories graded structures that side-stepped – rather than resolved – the debates over how to differentiate between the experiences of SLMP conceptualised as either mental imagery or hallucinations. For example, when considered side-by-side, these intermediate categories of SLMP can be seen to draw on overlapping combinations of characteristics to distinguish between mental imagery and various dysfunctional forms of SLMP on the one hand, and between hallucinations and various forms of non-pathological SLMP on the other.

As argued in Chapter Four, it was by being distanced in this way that the characterisation of mental imagery (as a concept used for investigating ordinary SLMP) and hallucinations (as a concept used for investigating pathological SLMP) could be stabilised – through an inversely related interdependence – into independent concepts for discrete experiences of SLMP. Therefore, while escaping the knowledge context within which these inverse characterisations provided (partial) explanations for the distinction between ordinary and pathological experiences of SLMP, the concepts of mental imagery and hallucinations continue to carry a shared series of associations inherited from the mediator-view of SLMP.

As these uses stabilised, the series of associations became embodied in the independent uses of these two concepts through the rarefied use of their inversely related 'typical' characterisations. For example, as we saw in Chapter Seven, the concepts of mental imagery and hallucinations were routinely used to individuate either ordinary or pathological experiences of SLMP based on one or more of their associated typical characteristics – without reference to the other concept. This was particularly evident in the way that the stated aims of those experiments documented within both Set-M and Set-H relied on their reader being familiar with both the concept used and the implicit series of associations that justified the uses of this concept in relation to the relevant epistemic goal. In this way, the concepts of mental imagery and hallucinations were able to be implicitly delineated in relation to each other, while also being used independently for the pursuit of discrete epistemic goals: mental imagery for investigating the various functions of SLMP, and hallucinations for investigating the dysfunction of SLMP.

The inverse characterisations of desirable and undesirable forms of SLMP can therefore be understood as having helped to individuate specific experiences of either mental imagery or hallucinations in ways that structured the routine uses of these concepts as independent tools for investigating ordinary or pathological SLMP in neuroimaging experiments. Furthermore, while this series of associations is no longer considered an adequate explanation of the relationship between ordinary and pathological SLMP, it nonetheless provides a structure of conceptual associations. It is these structured associations that carries-along the unacknowledged assumptions embodied by the distinction between the concepts of mental imagery and hallucinations; a distinction that ensures that each can be used independently of the other.

This reveals a tension between the current uses of the concepts of mental imagery and hallucinations as independent tools and the unresolved ambiguity highlighted by their historical interdependence. This tension remains largely unacknowledged. However, the difficulties that this tension present become obvious when comparing the uses of these two concepts as tools that are structured for investigating specific epistemic goals. Indeed, as demonstrated in Chapter Seven, even though the interdependence of these concepts was not recognised, the entrenched series of associations were routinely, if somewhat flexibly, drawn upon to inform a range of methodological choices.

8.5 Conceptual Contributions to Experimentally Generated Knowledge Claims

Entrenched associations about the inversely related interdependence of the concepts of mental imagery and hallucinations structure their uses as independent tools in neuroimaging experiments. Furthermore, the structured uses of these two concepts can be seen to have actively contributed to the knowledge generated in the neuroimaging experiments examined. This is the fourth step in the series of claims embedded in my central argument. Therefore, having clarified the relevance of these entrenched associations for structuring how these concepts operate as experimental tools for pursuing discrete epistemic goals, it is time to articulate how these structured uses *actively contribute* to experimentally generated knowledge.

To this end, it is worth returning to an element of conceptual practice partially obscured by the otherwise valuable metaphor of coral reefs. This additional element is, as Steinle (2010a, 213) points out, that sedimented concepts operate as a base for dynamic conceptual development within new sites of practice. In relation to this, it is important to appreciate the historical development of scientific concepts. As detailed in Chapter One, historicist approaches highlight that the situated usefulness of a concept can build up until the concept can be used (for investigating stable epistemic goals) without any explicit awareness of the structured fields of knowledge within which these functions emerged. As just discussed, this is evident in those examples in Chapter Seven where a given concept's entrenched associations precluded certain choices during the design, implementation, and interpretation of these experiments.

Put simply, the field of possibilities for a given experiment were constrained by the inversely structured uses of the concepts of mental imagery and hallucinations as tools for investigating their independent epistemic goals. In addition, the implicit associations embodied by each concept were such that many of the experiments would not have been pursued without them. Of course, this observation is related to broader issues that extend beyond the present scope – such as questions about the role of conceptual practices within experimental systems over extended time periods. However, for the present purposes, the question of interest is more specific: how did these conceptual constraints contribute to the divergent knowledges being generated from similar experimental findings? Therefore, rather than focus on conceptual development, I have explored how the structured uses of stable scientific concepts can operate as tools that contribute to the generation of first-order knowledge-claims within individual experiments.

As part of this I demonstrated – in Chapters Six and Seven – that there was a structured distance between the uses of the concepts of mental imagery and hallucinations that obscured the similarity of the SLMP-neuroanatomical-correlates reported in each case. This difference was evident in the way that these similar experimental findings were reported as contributing to diverging knowledge-claims in the articles from each set (matched for other variables – including the neuroimaging techniques, types of experimental conditions, theoretical variety, the disciplinary home of the researchers, and the publication expectations of the journals).

Despite these findings, it is important not to mistake the sedimentation of conceptual associations for a calcified local framework of dead coral that constrains the forms within which a specific concept can take within a given discipline. Of more interest is an examination of how the sedimented histories of a concept provide an evolving field of possibilities that both structure the adaptation of concepts for use in novel sites of practice and is itself transformed in the process. One way to pursue this approach is to draw on Pickering's descriptions of conceptual structures: as able to be transported from their original contexts into new practices; as embodying the disciplinary agency that participates in resistance-accommodation dances with human agency; and as both contributing to the knowledge generated in these practices and open to transformation in the process. Following this line of thought, conceptual tools can be understood to act – through the embodiment of disciplined performances of sedimented associations that structure the ways in which conceptual tools are used in the localised practices of individual experiments. It is these actions that can contribute to the heterogeneous resistance-accommodation interactions that emerge within experimental practice.

This point can be clarified by reviewing how the structured uses of the concepts of mental imagery and hallucinations participated in the three-way dances of resistance-accommodation that are evident in the reported methodologies of the neuroimaging experiments analysed. Recalling from Chapter One, this notion of a dance of resistance-accommodation describes dynamic human-nonhuman interactions from the perspective of human participants. For example, from the perspective of documented human intentions to pursue specific experimental aims, resistance denotes any impediment to these intentional aims; accommodation describes the choices that humans make in response to these obstacles. Within this context, conceptual tools embody the disciplined routines through which entrenched conceptual associations provide the limited array of possible sequences that can be reached from an arrangement, at a specific point in time, between the material, human, and conceptual elements of a given practice.

This limited array of possibilities can be illustrated with an example. In the articles examined, the scientists reported methodological choices that were in line with their stated intention of achieving a specific experimental aim (which related in some way to measuring the correlation between changes in neural activity and experiences of SLMP conceptualised as either mental imagery or hallucinations). As discussed earlier, these choices emerged within a field of possibilities constrained by the structured use of each concept for pursuing their discrete epistemic goals. In addition, the researches were sometimes met by unexpected fMRI measurements that did not immediately fit with their experimental aims or the epistemic goals of the concept used.[196] This suggests that the intentional choices reported in response to unexpected findings were not directly accommodating material agency (even though it may have been material agency that was captured by machines in ways that resisted human intention in the form of these unexpected results). Instead, these choices clearly align with the entrenched disciplined human performances embodied in the structured uses of each concept; an alignment that accommodated a type of resistance to human intention that was not even recognised as an obstacle in the first place.

I will return to this tangle of human-material-conceptual resistance/accommodation dynamics in the next section. For the moment, the point is that the human researchers made choices that passively accommodated the disciplined human performances embodied in the structured uses of each concept. This point can be illustrated by revisiting some of the documents analysed. Firstly, within Set-M, Kana et al. (2006, 2488, 2491) reported an

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[196] As discussed in Chapter Five, publications are tailored accounts of experimental practices (Schickore 2011, 471). As such, the unexpected results reported suggests that there might be other unexpected results that went unreported – perhaps accommodated instead by changes in the experimental set up too mundane to report. Accounting for how these were handled would be important for a fuller account of the material-human-conceptual dynamics of neuroimaging experimental practices. However, even within the limited scope of this project, the documented accommodation to unexpected results demonstrates that the structured uses of conceptual tools can play a role in this process.

unexpected result – over-activation within language-related brain regions in healthy subjects during the 'high-imagery' condition – and explained this as indicative of the involvement of verbal memory in the effortful process of transforming language-based information into sensory images. This is a reasonable explanation given their results. However, as there was no verification as to whether healthy subjects relied on imagery to comprehend these sentences or not, there are clearly alternative explanations. Furthermore, even if accepting that this was a justifiable choice, there is an unacknowledged assumption that experiences of imagery in healthy subjects requires volitional effort. As argued above, this assumption is based in the entrenched associations embedded in the concept of mental imagery rather than the actual characteristics reported during ordinary experiences of SLMP. As such, this type of explanation for unexpected results illustrates how scientists can choose to accommodate resistances met with in experiments by drawing on entrenched associations embodied in the disciplined routines for using a given concept. In this case, the conceptual relationship was between ordinary SLMP and volitional control (effort) – a relationship that sits at the centre of the series of mediator-view associations which underlie distinctions between mental imagery and hallucinations.

Secondly, similarly disciplined responses to unexpected results were evident within Set-H. For example, van de Ven et al. (2005, 646, 652) explained away an unexpected result from their study – a difference between the timing of measured neural activity and the reported presence of an SLMP experience – by drawing on the entrenched association embodied in the concept used. In this case, the association that provided the means of accommodating the resistance met was that subjects who hallucinate cannot be relied upon to report their SLMP experiences. Once again, choices made in response to this unexpected result appear to be constrained by an unacknowledged conceptual association that structured the accommodation to (potential) material resistance in such a way as to align with the structured use of the concept for pursuing a specific epistemic goal. In addition, the use of the concept of hallucinations can also be considered to have constrained the methods chosen to investigate dysfunctional SLMP. For example, as discussed in Chapter Seven, the entrenched associations about hallucinations contributed to the lack of interest in investigating the state of hallucinating (i.e., the presence of dysfunctional SLMP) as well as the emphasis on the value of studying hallucinating as a trait (of those subjects selected from clinical contexts where specific types of SLMP are reported). Indeed, while support for investigating the state of hallucinating increased within the Set-H sample over time, this approach remained constrained by expectations that subjects who hallucinate are unreliable sources of information about their own experiences.

To borrow Pickering's terminology, the active role that these entrenched conceptual associations played in these experiments highlights the resistance offered by the disciplinary agency embodied by specific conceptual structures. Building on this idea, these entrenched associations can be understood as having provided the structure for the independence of these interdependent concepts in a way that – through the disciplined routines of collective human performances – could each be used for pursuing discrete epistemic goals through the dynamic processes of resistance-accommodation between material, human, and conceptual elements of the experimental practice.

As already mentioned, these disciplined human performances were not discipline specific. Neither were they merely due to the representational role of these concepts in referring to a specific type of SLMP experience.[197] Rather, the structured uses of these

[197] It may be useful to reiterate that my approach focuses on questions that are distinct from those explored in relation to the role of representation in scientific practice (whether through the use of conceptual representations in the cognitive processes of scientists during experiments; as concepts entrenched within the broader social and institutional contexts which operate as external constraints on scientific practice; or the role of material representations as contributors to scientific practices). I have focused on conceptual tools – as human/non-human couplings that embody disciplined conceptual associations that intervene in within experimental practice to generating data.

concepts – as independent tools for investigating discrete epistemic goals – embodied entrenched associations that needed to be accommodated for within individual experiments. Structured in this way, using these concepts as stable inferential tools carried entrenched associations along within experimental practices. Entrenched within the inferential role of the concept, these associations actively contributed to the experiment. As these entrenched associations operated as a form of resistance that the research choices accommodated so that the material agency captured by fMRI machines could be stabilised in relation to the existing body of knowledge contributing to the epistemic goal in question.

These active contributions occurred through the uses of each concept in ways that were unacknowledged within the experimental methodology. These concepts were taken for granted – each was used as a reliable tool such that their roles in the experimental protocols did not need justifying. Indeed, as in the earlier examples, the choices through which to accommodate the resistance of an unexpected experimental finding were constrained by the structured uses of the conceptual tools. As discussed earlier, these unacknowledged constraints shaped not only the interpretation of the experimental findings, but methodological choices of experimental practices as well. It is these subtle, largely unrecognised resistances that were most evident in the analysis of the structured uses of these concepts when viewed from the perspective of human choices within the experimental practice (see Chapter Seven). Given this, the resistance offered to human intentions by the disciplined routines of conceptual associations provides the point at which the conceptual contributions to experimental practice might be considered analogous to the contributions

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It would be equally valuable to analyse these neuroimaging experiments from alternative perspectives. For example, focusing on the fMRI images themselves (and the MRI machines and related computer hardware and software programs that work with humans to generate them) could build on the intersecting literatures that highlighting how material agency is evident in the uses of both material representations (e.g., Nasim 2013; Vertesi 2015) and material instruments in scientific practice (e.g., Ihde 2009; U. Klein 2002).

of material instruments (a claim I develop in the next section). For now, the analysis offered demonstrates that similar experimental data was generated in experiments that used the concepts of either mental imagery and hallucinations in ways that contributed to diverging knowledge-claims depending on the disciplined performances embodied in the structured uses of each concept as independent of the other.

8.6 Comparing Conceptual and Material Contributions to Experiments

The structured uses of the concepts of mental imagery and hallucinations (as tools for investigating their respective epistemic goals) each contributed to the experimental methods documented as having generated the knowledge-claims reported in the articles analysed. As just detailed, this statement can be broken down and supported in four points: that each of these concepts intervened in the experimental methods reported in these documents; that the uses of each concept in these experimental methods were tied to specific epistemic goals; that the uses of each concept in pursuing these respective goals were structured by a shared series of implicit associations; and that the structured uses of these concepts contributed to the knowledge generated within experimental practice. With these four points clarified, it is possible to turn to the last claim: that the contributions of the structured uses of these concepts (as tools for investigating discrete epistemic goals) can be considered analogous to the active contributions of the material instruments within experimental practice.[198]

This claim builds on accounts that draw analogies between the contributions made to experimental knowledge by the material and conceptual elements of scientific practice (as each interacts with human elements). As detailed earlier, I focused on Pickering's (1995b, 158–59) analogy between material instruments and conceptual structures (where each

[198] It is important to note that – while emphasising that the material and conceptual contributions to experimentally generated knowledges are indicative of the contingency of these knowledges – these approaches also illustrates that this does not undermine the potential robustness of the knowledge generated in these ways (see Chapter One).

embody nonhuman agency in a way that can resist human intention). In addition, I drew on Feest's (2010, 180–82) analogy between instrument-use and concept-use (where each operate as tools that intervene in experimental practice). As argued in Chapter Two, the intersection between these two analogies suggests that conceptual tools operate as human/nonhuman couplings that – when structured by the routine human performances emerging within the material, human, and conceptual interactions within experimental practice – can act in analogous ways to semi-autonomous material instruments (such as machines).

Similarities between conceptual and material contributions to experimental practice are explicitly highlighted by these analogies. I discussed these in Chapter Two. For the present purpose, the value of this intersection lays in a specific possibility. This possibility is that the structured uses of concepts as tools can embody the disciplined routines of conceptual associations in ways that intervene in experimental practice; modifying experimentally generated knowledge in ways that are not entirely within the control of human intentions. It is this possibility that forms the bridge between accounts of material agency in STS and HPS accounts of conceptual tools that developed in Chapter Two. With this possibility in mind, my claim can once again be grounded in the concrete specificity of the localised practices that I examined. In this way, my claim can be rephrased: the structured uses of the concepts of mental imagery and hallucinations (as tools for investigating specific epistemic goals) actively contribute to experimentally generated knowledge in ways that are like the active participation of material instruments.

In relation to this possibility, it is worth recalling that the STS accounts of material instruments introduced in Chapter One emphasise that nonhuman participants in scientific practice actively contribute to the generation of scientific knowledges by participating within the heterogeneous interactions that make up scientific practice. One way of appreciating how nonhumans participate is through the notion that machines can make 'non-neutral' modifications that actively contribute to the intentional situation of humans when gathering the knowledge produced from human/nonhuman interaction (Ihde 1979, 49, 78). Another way of highlighting the active contributions of material nonhumans in the dynamic process of knowledge generation has been to emphasise investigative techniques – such as the *Crittercam* mentioned earlier – that hybridise human scientists, nonhuman-animals, and various technological equipment in inextricable ways that each modifies the other during the process of generating knowledge (Haraway 2006, 176–85).

As I detailed earlier, the structured uses of conceptual tools within experimental practice intervene in experimental practice in ways that modify human intentions even while these interventions are inextricably enmeshed within the human/material/conceptual interactions involved in generating knowledge. In relation to this, I argued that conceptual tools can be understood to act – through the embodiment of disciplined performances of sedimented associations that structure the ways in which conceptual tools are used in the localised practices of individual experiments. I propose that it is these actions that contribute to the heterogeneous resistance-accommodation interactions that emerge within experimental practice. In relation to this argument, the structured uses of concepts as tools for investigating specific epistemic goals can be understood as a collection of human/nonhuman actions that intervene in experimental practice to modify the knowledge generated in ways that are not entirely within the control of human intentions.

These similarities between the contributions of material instruments and the 'structured uses of concepts as tools for investigating specific epistemic goals' are analogous; not equivalent. Even so, the analogy is striking. For example, recall that these ambiguously delineated concepts of mental imagery and hallucinations were used as unquestionably independent and *reliabl*e tools – tools that did not need to be refined in any way and would operate with minimal direction. As is often the case with reliably-working material instruments, the work that each conceptual tool did within the various aspects of these experiments was therefore largely taken for granted. At the same time, although their function for pursuing a specific epistemic goal was not questioned, these conceptual tools were still open to transformation with the experimental dynamics (also like material instruments which are often tinkered with in unreported ways).[199] Indeed, as discussed in Chapters Three, Five, and Seven, the uses of each concept are frequently adapted to the dynamics of local contexts.

Examples of these routine tool-uses can be found in the unmarked adaptation of the concept of mental imagery when used in 'resting-state' fMRI experiments. As detailed earlier, although abandoning one of the characteristic distinctions between ordinary and pathological SLMP, this adaptation did not include any attempt to delineate the type of phenomena being investigated (ordinary spontaneous SLMP) from other types of spontaneous SLMP (other than using the concept of mental imagery). Furthermore, despite investigating spontaneous experiences of SLMP, the goal was to investigate how imagery contributed to ordinary thought processes. Therefore, within this flexibility, the structured uses of these tools for investigating specific epistemic goals continued constrain the field of possibilities – prompting some research pathways while obscuring alternative avenues down which the human-material-conceptual interactions could have developed.

This observation draws attention to the tension between the path-dependence and emergent transformations of the human, material, and conceptual contributions to scientific practice. As detailed earlier, this tension forms a key element in Pickering's notion that nonhuman agency resists the intentional elements of human agency. Having emphasised the

[199] For example, see Pickering's (1995b, 53) discussion of the of the bidirectional 'tuning' that occurs when material instrument and humans interact – a process that is not necessarily recorded in scientific accounts of material practice.

value of this analogy, this tension also highlights that, while contributing to scientific practice in analogous ways, the disciplinary agency captured by conceptual structures and the material agency captured by machines should not be considered equivalent. The material agency that the experimental intentions of humans must accommodate emerges as the resistance offered by the world *doing whatever it will* (regardless of whether this is relevant to the reported aims in the experiments analysed). In contrast, the resistance that the experimental intentions of humans met from disciplinary agency is a result of the accretion of disciplined human performances. These routinised performances carry conceptual associations along, independently of human intention, to structure the dynamic uses of concepts within scientific practice. Understood in this way, disciplinary agency is something that emerges *within* scientific practice rather than as something external that hampers the otherwise direct human-material interactions.

Viewed in this way, disciplinary agency can be understood as the actions of the disciplined human routines that, embodied in the structured uses of conceptual tools for pursuing specific epistemic goals, contribute to scientific practice. However, despite these differences, it is difficult to identify how an experimental aim is being resisted during the emergent dynamics of that experiment. This difficulty can be demonstrated by considering the ways in which the choices made by intentional human agents can be understood as responses to multiple points of resistance – including from material and/or conceptual elements of practice that may or may not converge. For example, even an obvious point of resistance – say a result that is at odds with, or orthogonal to, the aims of an experiment – could indicate a range of different possibilities.

The possibilities in this one example alone are daunting. Firstly, the unexpected result may indicate that there is resistance from the aspect of the world being investigated (which should be accommodated by altering experimental aims). This could be because the obstacle indicates something about the intended approach to measuring the aspect of the world of interest (SLMP-neuroanatomical-correlates) that needs to be adjusted to provide an account of this unexpected aspect of the phenomena being investigated.

Secondly, the same unexpected result could indicate experimental noise – resistance from material agency and/or disciplinary agency unrelated to the aspect of the world of interest (that could more sensibly be accommodated for by refining the material and/or conceptual tools). In this case, the obstacle to the stated aims may indicate an artefact of the instruments that is not directly relevant to the aspect of the world of interest – say a bug in the fMRI software or an imprecise use of the concept to individuate instances of the phenomena of interest – that needs to be modified to ensure that the data the instrument generates is measuring the aspect of the world it is intended to.

A third option is that the same unexpected result indicates resistance from the disciplined conceptual associations that structure the use of concepts as data-generating tools. If so, then the difficulty presented by the unexpected results may indicate that one of the entrenched conceptual associations needs to be reviewed – say the association between experiencing a lack of volitional control over SLMP and the expectation that this indicates an individual failure to make reasoned judgement about the perceived world.

Put simply, multiple choices can be made to reduce the resistance that human agents meet in experimental practice; choices that may not necessarily accommodate the source of the resistance directly. For example, when met with resistance, scientists may choose not to refine the material and/or conceptual tools they use for measuring the aspect of the material world of interest; instead unintentionally aligning the scientific accounts of the world with the disciplined conceptual associations that structure how these tools are used. In many cases this may be justified. However, if so, it seems reasonable to argue that such alignment should be explicitly justified.

In the articles examined this was not done: methodological choices involving the uses of the concepts of mental imagery and hallucinations were always reactive and unarticulated – let alone justified. Examples of this can be found in my account of the routine uses of these concepts during subject selection, methodological choices relating to the relevance of SLMP experienced during scans, experimental aims, and the experimental conditions. In each case, the role of these concepts was never questioned. Instead, these concepts operated as reliable tools that – presumed to have individuated the SLMP of interest (during subject selection) – need not be questioned further.

The concepts of either mental imagery or hallucinations were used in ways that drew on disciplined conceptual associations to align experimental practices with specific epistemic goals without any (reported) consideration of alternative options. In such cases, it is possible that when choices unwittingly accommodated disciplinary agency (rather than material agency) they obscure something about the aspect of the world being investigated. This is not simply a matter of bad choices. Instead, these unjustified choices form in response to disciplined conceptual associations that provide an avenue for unintentionally side-stepping the difficulties presented by (potential) material sources of this resistance (including those from the type of phenomena being investigated).

This type of reactive choice – to respond to a given instance of resistance by accommodating the disciplined routine associations embodied in conceptual tools without justification – can be seen in the analysis offered in Chapters Six and Seven. It is particularly evident in the examples I used to illustrate the way that unexpected results were reported. In these examples, the unexpected result could have been accommodated in a range of ways – including re-evaluating the experimental aims or by listing limitations of the experiment that suggest ways for refining the material and/or conceptual tools used to measure correlations between hallucinations and neurocognitive processes. However, instead of considering the potential limitation of the experimental aims and/or tools, unexpected results were often explained away as inconsequential.

Two specific examples from the sets of articles examined earlier were the documented responses to unexpected results by van de Ven et al. (2005, 646, 652) and Kana et al. (2006, 2488, 2491). In both these cases, methodological choices were made in response to the entrenched associations of the relevant concept for SLMP without any discussion as to *why* these alignments were appropriate. In such cases, explanations relied on the entrenched associations embodied within the relevant concept used for investigating SLMP in the neuroimaging experiment reported. As such, these entrenched conceptual associations framed the choices that researchers reported making when overcoming potential obstacles to pursuing their experimental aims (and the relevant epistemic goal). In doing so, these explanations can be seen to accommodate the disciplinary agency embodied by the conceptual tool used to investigate the SLMP of interest.

In this way, the concepts or mental imagery and hallucinations can be understood as tools that were each used in line with the disciplined routines of conceptual associations to pursue specific epistemic goals that, like material instruments, embodied a force that resisted human intention. Furthermore, the tension between the current uses (as independent tools) and the unresolved interdependence evident in their intersecting histories can be seen to form an integral part of the way that human agents attempt to accommodate the resistances they meet in material practice. An integral part of these dynamic practices, these entrenched conceptual associations contributed the limited yet flexible array of possible conceptual sequences that could be reached from the emergent arrangements of material, human, and conceptual elements within a given experiment.

This account emphasises the contributions of the disciplined routinised actions embodied by the structured uses of these concepts as tools for pursuing specific epistemic goals. However, I do not intend to imply that these conceptual tools were not being modified along the way. Indeed, as is evident in Chapter Three, the characteristics that help to individuate distinct types of SLMP have been adapted in different contexts (see Tables 2, 3, and 6). As discussed earlier, these adaptations continue to draw on the entrenched associations carried by these concepts. Even so, these changing characterisations of each concept in different context highlight potential shifts within clinical practice. Positioning these shifts within their historical contexts offers challenges to the independent uses of these interdependent concepts.

I expect that experimental practices will eventually respond to the challenges that the clinical transformations of each concept present; as well as contribute additional challenges in turn. However, within the time-period for published neuroimaging experiments that I considered (2004-2014) the structured uses of the concepts of mental imagery and hallucinations above were relatively stable. Given this, any change in the routines of using these tools is likely to have occurred slowly and in ways that were not recorded as relevant to the documented experimental methods. Whatever the reason, any shifts in the entrenched conceptual associations embodied by the concepts of mental imagery and hallucinations were almost imperceptible in the decade of neuroimaging experiments examined. Instead, the structured uses of concepts as tools for investigating specific epistemic goals operated like stable mundane material instruments: reliable tools, appropriate for the purpose at hand, and entirely taken for granted.

As demonstrated earlier, the structured uses of mental imagery and hallucinations as conceptual tools for pursuing specific epistemic goals actively contributed to the dynamics within neuroimaging experiments. These dynamics generated knowledge-claims stable enough (at least momentarily) to operate as (potentially) robust accounts of the aspect of the world being investigated.[200] Positioned in relation to the active contributions of material instruments, this concrete argument offers support for a more abstract claim: that the structured uses of conceptual tools can contribute to the knowledge generated in experiments in ways that can be considered analogous to the active contributions of material instruments. This analogy positions concepts as tools that carry-along contingent routine associations that can interact with material and human elements of scientific practice in ways that human then choose *how* to respond to (without realising why the choice is required in the first place). That is, while not equivalent and far from the equal to the actions of material instruments, the structured uses of conceptual tools embody entrenched associations that can actively contribute to scientific knowledge.

This series of arguments rests on earlier chapters and emerged from my investigation of a specific puzzle. To acknowledge this, the next section concludes this thesis by reviewing how each chapter connects with both the puzzle that prompted this research and my subsequent view that the concepts of mental imagery and hallucinations operate as structured tools that actively contribute to the knowledge generated by neuroimaging experiments.

[200] As noted in Chapter One, following the proposal of an experimental knowledge-claim (stable as it might be) there are additional convoluted processes involved in mobilising and further stabilise that experimental first-order knowledge-claims before it (or something like it) become accepted as a scientific fact.

Conclusion

Drawing on three themes within historical, philosophical, and social studies of scientific practices, this thesis examines the documented *uses* of two scientific concepts – mental imagery and hallucinations. This examination highlights how the historical interdependence of these two concepts offers insights into a puzzle that emerges when comparing documented experiments. This puzzle centres on the equivalent SLMP-neuroanatomical-correlates that are reported regardless of whether the SLMP experiences are conceptualised as mental imagery or hallucinations.

As discussed earlier, if mental imagery and hallucinations both conceptualise types of SLMP then some overlap in the experimental findings should be expected. More puzzling is the dismissal of these overlaps as trivial. Disinterest in these overlaps may be partially explained by the independent uses of these two concepts: mental imagery and hallucinations are each routinely used without any reference to the other concept. However, the treatment of these overlaps as trivial continues even when these two concepts are used together. For example, when either concept is used in relation to the other it operates merely to illustrate that the SLMP of interest is distinct from various other types of SLMP experiences. As such, there is an expectation that unique SLMP-neuroanatomical-correlates will be found for both mental imagery and hallucinations respectively. This expectation is typically justified by the inverse set of characteristics relied upon for differentiating between ordinary and abnormal SLMP experiences. However, as argued in Chapter Three, these 'typical' characterisations are insufficient for explaining the independent uses of the concepts of mental imagery and hallucinations in experiments that investigate the role of SLMP in neurocognitive function and dysfunction respectively.

The literature outlined in Chapters One and Two offers a novel avenue for examining the puzzle that emerges from the expectation that unique SLMP-neuroanatomical-correlates underlie experiences of mental imagery and hallucinations respectively. In Chapter One, I drew attention to two of the strands of research that contribute to historical, philosophical, and social studies of scientific practices: *STS* accounts of material agency and *HPS* accounts of concept-use. In exploring these two strands in relation to each another, I demonstrated that their convergence can be understood in relation to three themes within the broader literature: a recognition that material instruments contribute to scientific knowledge; an interest in the uses of concepts in experiments; and an appreciation for the historical conditions within which current practices emerge.

To explore these broader themes, I took Pickering's analogy (between conceptual structures and material instruments) and positioned it as bridge between STS accounts of material agency and HPS accounts of concept-use. Then, building on the scaffolding offered by this bridge in Chapter Two, I argued that these converging insights suggest productive avenues for examining the unintended contributions that the structured uses of specific concepts may make to the generation of experimental knowledges. The avenue I then developed focused on analysing the uses of concepts as tools that are structured for investigating specific epistemic goals.

This avenue of research proved valuable in examining the uses of the concepts of mental imagery and hallucinations in neuroimaging experiments. In this context, each concept (mental imagery and hallucinations) can be understood as individuating a specific type of phenomena (desirable and undesirable SLMP respectively) in unrelated investigations (studying either ordinary or pathological SLMP) in purist of pursuit of separate goals (understanding the role of SLMP in functional or dysfunctional neurocognition). For example, as I have argued elsewhere, the current uses of mental imagery and hallucinations – as independent tools for pursing discrete goals – simultaneously reflect and obscure the interdependent associations each concept inherited from past mediator-views of SLMP (E.

T. Smith 2018). In addition, in Chapter Four I offered a more detailed account of how these interdependent associations came to structure the independent uses of the concepts of mental imagery and hallucinations in experiments that pursue discrete goals.

This appreciation of the historical context offers an avenue for exploring the puzzling practice of ignoring the equivalent SLMP-neuroanatomical-correlates being reported for both mental imagery and hallucinations. To this end, Chapter Five through Eight details a series of comparative analyses about the uses of these two concepts in experiments that report such similar findings. In Chapter Five I explained the multi-method approach I developed for examining the documented accounts of these experimental practices. In brief, this method involved three stages. Firstly, I took a meta-analytic approach to collecting a representative sample of peer-reviewed publications reporting experimental findings of SLMP-neuroanatomical-correlates (where the SLMP experiences were conceptualised as either hallucinations or mental imagery). Secondly, I used a mixed-methods approach to identify four article subsets. Each subset consisted of articles where a given brain region (the STG, IFG, IPL, or MFG) was reported as relevant to investigating SLMP (either mental imagery or hallucinations). These four overlapping article subsets provided paradigmatic examples of fMRI experiments that report overlapping findings regardless of whether the concept of mental imagery or hallucinations was used to individuate the type of SLMP of interest. Thirdly, I took a summative content-analysis approach to develop criteria for a qualitative analysis of how these two concepts were each used within published accounts of fMRI experiments.

Following this method, I identified a selection of SLMP-neuroanatomical-correlates that were reported in both the Set-M and Set-H articles. In doing so, a key contrast was identified. Specifically, that SLMP-neuroanatomical-correlates reported by articles in both Set-M and Set-H were never taken to indicate that distinct types of SLMP share some neuroanatomical process. Instead, these equivalent findings were taken as indicative of the distinct mechanism expected for the SLMP of interest (either mental imagery or hallucinations). Within Set-M, each finding provided evidence for claims about the neurophysiological mechanisms underlying the role of mental imagery in various neurocognitive functions. Within Set-H, each finding provided evidence for claims about the neurophysiological mechanisms underlying the dysfunctional role of hallucinations in neurocognition.

The differences between these knowledge-claims was further explored, in Chapter Six, through a comparative analysis of the four most common ROI within which these overlapping findings were reported. This comparison demonstrated that equivalent findings were interpreted to support various first-order knowledge claims; claims that diverged depending on whether the SLMP-neuroanatomical-correlate in question had been identified in an experiment using the concept of either mental imagery or hallucinations. As detailed earlier, this comparison held even when considered across multiple disciplines, theoretical commitments, and a range of methodological techniques. As such, I then positioned this comparison within the context of my earlier proposal, developed in Chapter Two and Four, that scientific concepts carry entrenched associations that structure their uses as goal-directed tools in experiments. Further developing this analysis, I argued that the knowledge-claims generated from a given SLMP-neuroanatomical-correlate were framed by entrenched associations of the concept used to individuate the type of SLMP investigated (either mental imagery or hallucinations).

Building on this point in Chapter Seven, I demonstrated that the structured uses of these two concepts also played an active role *prior* to framing the knowledge-claims generated by experimental findings. Based on this, I argued that the uses of the concepts of mental imagery and hallucinations – structured as tools for investigating discrete epistemic goals –

provided the conditions within which methodological choices were made for investigating SLMP in relation to either ordinary or dysfunctional neurocognitive processes.

Finally, in Chapter Eight, I linked this comparison of current practices (Chapter Five through Seven) together with the earlier arguments developed in Chapters Two, Three, and Four. In doing so, I sought to articulate my over-arching thesis: in the case of mental imagery and hallucinations, it is their *structured uses* (as independent tools for investigating specific epistemic goals) that actively contribute to the knowledge generated in neuroimaging experiments investigating SLMP; contributions that are analogous to, yet not equivalent with, the active contributions of material instruments.

At this point, it is important to note that my approach highlights some features of the experimental practices examined while obscuring others. Alternative historiographical approaches and different analytic perspectives would highlight other salient features of the dynamics of neuroimaging experiments (see: Camilleri 2015; Vertesi 2015). In addition, my arguments need to be taken within the context of the specific *neuroimaging practices* my analyses focused on. Any attempt to extrapolate my arguments to experimental practices more generally risks ignoring the complexity of research activity and epistemic processes evident in other cases of current and historical scientific practices (see: Steinle 2016, 312).

With these caveats in place, it is worthwhile highlighting how the lessons provided by this concretely descriptive account might offer insights relevant to broader issues discussed in relation to studying scientific practices. For instance, my research supports existing proposals that the complementary strands of research within STS and HPS each contribute to the broader field of historical, philosophical, and social studies of the sciences.[201] For example, my account of concept-use in a small set of documented fMRI experiments

201 For example, see: (Arabatzis and Schickore 2012, 399; Rouse 2011b; Soler et al. 2014).

contributes to the long-running trend of studying non-human contributions to experimental practices within historical, philosophical, and social studies of the sciences. In addition, my research provides a further example of the value of positioning scientific concepts within their historical contexts when developing philosophical accounts of current scientific practices. In each case, these approaches help to explore how entrenched conceptual associations interact with material and human elements of scientific practice; interactions that are actively contributing to scientific knowledge in rarely recognised ways. Indeed, far from being merely exceptional case of 'bad practice' (to be weeded out from more common higher standards), my research converges with others to suggest that that the unrecognised contributions of using concepts as tools is part of *standard scientific practices* (at least within the field of neuroscientific experimental research).

It is also worth returning to two additional points of interest that, although raised by my research, have unexamined implications that are beyond the scope of my analyses. Firstly, in Chapter Three I gestured towards the possibility of examining the diversity of SLMP experiences in experimental neuroimaging practices. My account of their historical interdependence (in Chapter Four), suggests that this possibility could be explored by engaging with the diverging knowledge claims that the independent uses of each concept generate in neuroimaging experiments (detailed in Chapter Six). Likewise, my starting point of viewing of scientific knowledge as objective-yet-situated (see Chapter One) raises the question of how we could make sense of the diverging knowledge-claims generated in relation to SLMP-neuroanatomical-correlates reported for different types of SLMP. There are many ways that this question could be interrogated; each of which would require additional research.[202] At a minimum, my analysis of individual documented experiments is

[202] For example, perhaps these claims indicate the co-existence of tangled multiple realities that can both clash and depend upon one another (Mol 1999, 83–85); or, perhaps these diverging claims indicate the multiple ways that human-material (and conceptual) interactions can enforce multiple

limited by the minimal consideration given to context where these two concepts are used differently. For example, although briefly mentioned in Chapter Three, I have not systematically analysed the shifts within clinical practices towards understanding distressing experiences of SLMP as related to factors other than the specific characteristics of SLMP itself (regardless of whether such experiences are conceptualised as mental imagery or hallucinations).[203]

The second additional point returns to questions about neuroimaging experiments themselves. While my research is intended to contribute to discussions within historical, philosophical, and social studies of the sciences, my findings may have relevance to debates emerging within neuroimaging research communities. In particular, my research converges with calls for addressing conceptual challenges within neuroimaging experimental practices (Abend 2016; M. L. Anderson 2015; Poldrack and Yarkoni 2016). For example, as mentioned in Chapter Five, one recognised conceptual challenge is that cognitive ontologies are inherited from a psychological taxonomy of concepts for cognition based on behavioural observations that is not being updated in light of neuroscientific knowledge (Bunzl, Hanson, and Poldrack 2010, 54; Lenartowicz et al. 2010, 690). In relation to this, Russell Poldrack and Tal Yarkoni (2016, 591) have proposed that knowledge-claims often depend on tacit associations tied to these outdated cognitive taxonomies rather than explicated in the formal inferences about the neuroimaging data. These entrenched associations are recognised as contributing to practices where different putative causes are being invoked to explain a given observable outcome depending on the context (Poldrack and Yarkoni 2016, 591).

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productive ways of 'seeing as' that focuses attention on specific features of the same complex processes (Vertesi 2015, 29–33).

203 In this context, developments on Ian Hacking's (1995b) description of the 'looping effects of human kinds' (e.g., Tekin 2014) offer potential avenues for analysing the biopsychosocial processes proposed for the distress associated with some SLMP and not others.

Furthermore, it is possible – at least in principle – to explicate the tacit conceptual and material assumptions that underlie specific experimental inferences in ways that can drive further research in areas of epistemic uncertainty (U. Feest 2016). My approach illustrates one way to explore this possibility: by developing an historically informed philosophical engagement with those (potentially) outdated concepts that continue to be used as tools in neuroimaging experiments.[204] Therefore, although the aims of my research were more modest, my some of findings support concerns about out-dated conceptual tools increasingly expressed by neuroscientists.

Putting these speculative considerations aside for future research, allow me to conclude. My thesis is that the interdependent concepts of mental imagery and hallucinations came to be used as independent tools for pursing specific epistemic goals within fMRI experiments – uses that are structured by their historical interdependence in ways that actively contribute to experimentally generated knowledge. This account builds on converging insights from STS and HPS through a series of comparative analyses of the concepts of mental imagery and hallucinations. In doing so, I asked how each concept is distinguished from the other; how their historical developments intersect; and how each is used in fMRI experiments. In answering these questions, I demonstrated that independent uses of the concepts of mental imagery and hallucinations rely on interdependent associations; associations that become entrenched in the structure provided by their routinised inverse characterisations (as proxy explanations for functional and dysfunctional SLMP respectively). It is within this structure that the interdependent concepts of mental imagery and hallucinations each came to be used,

[204] For some examples of the ongoing discussion of these issues, see: (Bassiri 2015; Fitzgerald and Callard 2015; Henman 2013; Hanson and Bunzl 2010; C. Klein 2010; J. B. McCaffrey 2015; Poldrack and Yarkoni 2016).

independently of the other, for investigating discrete epistemic goals within neuroimaging experiments.

Understood within this historical context, I have argued that these concepts function as mundane tools for investigating stable epistemic goals within individual experiments; tools used without any explicit awareness of the structured fields of knowledge within which these functions emerged. This argument emerged from a comparison of documented fMRI experiments using the concepts of mental imagery or hallucinations to identify equivalent SLMP-neuroanatomical-correlates in ways that can generate conflicting knowledge about neurocognition (as functional or dysfunctional respectively). In these experiments, using the concepts of mental imagery or hallucinations obscured the similarity of the SLMP-neuroanatomical-correlates reported in these experiments. Instead, the structured uses of each concept as independent tools drew on their interdependent associations to focus on how these findings support unique knowledge claims about the type of SLMP of interest. This was highlighted by the role of implicit conceptual associations helping to align experimental practices with contrasting epistemic goals rather than prompting public consideration of alternative options. Furthermore, I demonstrated that the disciplined routines of conceptual associations structured the uses of these concepts for pursuit of specific epistemic goals, precluding certain choices during the design, implementation, and interpretation of the fMRI experiments examined.

As such, while focusing on the uses of just two concepts as used within individual experiments, my research converges with a diverse range of proposals calling for more careful examination of the tools used in generating scientific knowledge. In this context, I have sought to demonstrate that examining the *structured uses of concepts as goal-directed tools* offers an additional avenue for examining how the heterogeneous dynamics of experimental practices come to contribute to scientific knowledge in unintended ways.

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Appendices

Appendix 1 (Annotated Glossary)

Following is an alphabetised list of terms, initialisms, and phrases where additional context may help clarify my choices within the main text. Major cross-references indicated in bold.

abnormal SLMP

Experiences of **SLMP** that are unusual or unwanted. The abnormality may stem from these SLMP being either (1) disruptive and/or distressing experiences reported in clinical contexts (e.g., **hallucinations**) or (2) reported by a minority within the non-clinical population (e.g., **non-pathological hallucinations)**.

actants

Within the STS discourse discussed, an actant can be any entity that acts in the world to constitute knowledge through collaborative performances (Casper Brunn Jensen 2003b, 228, 230; Latour 1999, 15–16, 303–8). For example, **nonhuman** actants are sometimes described as having **material agency** such that they become **active participants,** along with humans, in the practices that generate **scientific knowledge**.

active contributions

Within the STS discourse discussed, intentional and non-intentional actions are part of the human-nonhuman interactions that come together to form the collaborative performances that form scientific practices.

To make an 'active' contribution to a given situation, an entity must *act* in a way that changes something about the situation within which it is participating. These actions can be:

- Intentional actions (deliberate acts). The principle example in scientific practice are the goal-directed actions of human researchers;
- Non-intentional actions (acts that are automatic, reflexive, reactive, accidental, instinctive, or otherwise unintended). In scientific practice, this includes the actions of **nonhumans** such as material instruments. For example, a centrifuge acts to separate substances based on relative density.

activity

See neural activity

agency

Within the STS discourse discussed, agency can be understood as a force that acts in the world, intentionally or otherwise, via the relational performances of **actants.** As discussed in Chapter Two, agency can be seen in goal-oriented acts, but also in **actions** that are non-intentional – see: **human agency**, **material agency,** and **disciplinary agency.**

AVH (auditory-verbal hallucinations)

AVHs are the most commonly studied type of **hallucinations.** They are experienced in the auditory **modality** that are, compellingly 'as if' hearing one or more voice. Sometimes referred to as **hearing-voices** or as voice-hearing experiences, AVHs are one of the most commonly investigated types of hallucinations. Experiences of AVHs are closely associated with a range of psychiatric disorders – most famously, schizophrenia.

black boxes

Within STS, there has often been a focus on opening up the *black boxes* of science (Latour 1987; Pinch 1992; Winner 1993; *STS – Opening the Black Box* 2011). In this context, black boxes occur as a process where the complex processes have become opaque through the stabilised associations that are no longer questionable (except at a heavy cost). Studying these complex practices provides a view of how these practices came to be and/or how they operate while maintaining their opacity. There are parallels between this metaphor of black boxing and the metaphor of **sedimentation** (partially adopted in Chapters Two and Eight).

bodies of knowledge

I focus on the uses of concepts as instances that articulate elements within the dynamic *bodies of knowledge* that have been accrued by communities within specific shared practices (rather than an element of either individual cognition or major social systems of thought). For example, I draw on Feest's (2010, 173) description of **scientific concepts** as **individuating** a type of phenomena for further investigation by delineating the class of phenomenon of interest from other types of phenomena within an available body of knowledge. Likewise, I briefly mention Rheinberger's (2005b, 320 emphasis added) use of Bachelard's description of "the instrument as representing the material existence of a body of knowledge [at any given time", and emphasises that this materially instantiated body of knowledge contributes to dynamic process within which "phenomenon and instrument, object and scientific spirit, concept and method are all joined in a process of mutual instruction." In each case, these approaches continue a tradition of examining bodies of knowledge *(connaissance)* in relation to the specific conditions of knowledge *(savoir)* within which the elements of these accrued bodies knowledge came to be used (as concepts, instruments, institutions, etc.,) in current practices (Foucault 1972, 202; McHoul and Grace 1993, 9–11).

characteristics

Unless otherwise specified, *characteristics* refer to those features of a type of phenomena that helps to **individuate** instances of that phenomenon for further investigation. In this case of **SLMP**, these are those **phenomenological** characteristics as identified through surveys, questionnaires, first-person reports of metacognitive processes, and other introspective methods. These phenomenological characteristics can be understood as 'phenomenal properties'. This term, borrowed from Katalin Farkas (2013), highlights the perceptual similarity of the phenomenological characteristics considered typical of various forms of SLMP. The notion that mental experiences can share common phenomenal properties with the relevant modes of perceptual experiences can be clarified by borrowing Farkas' (2013, 399) examples that "if two experiences both involve feeling cold they share a phenomenal property; if two experiences both involve something appearing blue, they share another phenomenal property".

For example, in the case of **hallucinations**, the set of typical characteristics emerged from attempts to explain why these SLMP have a compelling sense of perception (see Chapter Four). These characteristics are: a high degree of perceptual similarity, 'projection' into perceptual space, and/or the involuntary or uncontrollable nature of the experience (A. Aleman 2001; Slade and Bentall 1988; David 2004). While, the set of typical characteristics associated with **mental imagery** emerged through attempts to explain how some SLMP can be experienced as resembling perception without being confused for it. These characteristics are: internal location, self-production, controllability or manipulability, and a low degree of perceptual similarity (Stephen M. Kosslyn, Ganis, and Thompson 2010, 3; Roeckelein 2004, 11, 68; Waller et al. 2012, 293).

concepts

See: scientific concepts

conceptual practice

Unless otherwise specified, I am following Feest and Steinle (2012, 4) in considering conceptual practice as the dynamic temporal processes connected to the uses of **scientific concepts** by communities (rather than as individual cognitive processes). Consistent with this, in Chapter Two I draw on Pickering's (1995) description of conceptual practice as a temporally **emergent** process involving **resistance-accommodation dialectics** between human intention and the force of **disciplinary agency** embodied by **conceptual structures.**

conceptual structures

Unless otherwise specified, I am following Pickering's (1995) use of the term conceptual structures as the structured associations that embody the systematic 'machine-like actions' of **conceptual practice** to align, and translate between, multiple elements of scientific culture. For Pickering (1995b, 29, 115–16, 146), conceptual structures include everything from mathematical formulae and theoretical models to conceptual systems and conceptualisations of phenomena. However, given my focus on scientific practice, I am less interested in the conceptual practices involving symbolic formulations or theoretical modelling. I develop this notion in relation to other approaches to conceptual practice in Chapter Two.

conditions of possibility

The material, conceptual, and social conditions that combine to provide the possibility for a specific form of scientific knowledge to be generated. These possibilities emerge unpredictably from the various interacting **conditions of production** that contribute to the generation of scientific knowledge. For

conditions of production

The material, conceptual, and social conditions that combine to provide the emergent **conditions of possibility** within which a specific form of scientific knowledge can be generated. This phrase emphasises the **contingency** of scientific knowledge.

connectivity (neural)

Neural connectivity in this context refers to the coupling between the **neural activity** measured within two or more specified brain regions (as discussed in Chapter Five).

constructivism

Constructivism is a term that some scholars use to distance views that scientific knowledge is contingent on the material and social conditions of its productions from the dangers of suggesting that scientific knowledge is constructed via an 'anything goes' relativism (a view typically associated with **social-constructionism**). For some examples of explicit rejections of social-only explanations for scientific knowledge, see (Boon 2015a; Daston 2000a; Galison 1995; Haraway 2004, 225; Ihde 1979, 4, 2009, 75; Latour 1993, 6; Law 2002; Pickering and

Stephanides 1992, 160; Pickering 1995b, 12; Robins 2012). Related approaches are also developed as variations of realism (e.g., Barad 2007). Also see: **realism/relativism debates.**

contingency of scientific knowledge

To say that something is contingent is to highlight that the given thing or event is neither necessary, nor impossible. Interest in contingency has played an important role in developing the view of **scientific knowledge** detailed in Chapter One. This view, positions scientific knowledge as able to provide accounts of reality (as it exists independently of human access to it) that are simultaneously objective (in the sense that they can be robust and intersubjective) and contingent (that is, situated within the conditions of its generation)

Within the **STS** context, the contingency view of scientific practices has been extended to explore the ontologies of the people and things that co-evolve in unpredictable ways within these dynamics activities (e.g., Latour 1993; Pickering et al. 2010; Pickering 2015). I have not explored this extension; however it would be interesting to consider these extensions in relation to the recent interest in contingency/inevitability debate emerging in the overlap between **STS** and **HPS** (see: Soler 2015). Similarly, there are important implications of these approaches for specific issues being discussed within fields of critical theory, activism, and politics that are beyond the present scope. For an example of the value of this type of extension, see Barad (2007, chaps 5, 6).

deluded imagination

A term proposed by W. Battie (1758, 5–6) for "the perception of objects not really existing or not really corresponding to the senses [and] a certain sign of madness".

diachronic

Of, or pertaining to, the changes over successive points in time. For example, diachronic accounts of science often introduce genealogical hypotheses involving asymmetric temporal and causal relations between entities or states of the systems described (Cat 2017). Compare: **synchronic.**

disciplinary agency

A form of **agency** that can be understood as the forces of disciplined human performances that carry conceptual practice along independently of human intention. For Pickering (1995b, 115), disciplinary agency is embodied by conceptual structures and can resist human intentions. In Chapter Two, I argue that *disciplinary agency* – as described by Pickering – could just as readily be developed within a given experimental system as within a specific discipline and that, in either case, the agency of these disciplined performances frequently being carried from the specifics of their development into new research contexts.

eidetic imagery

Eidetic imagery was used to conceptualise a form of **SLMP** that did not fit into the typical characterisations of either mental imagery or hallucinations (peaking I use during the twentieth-century). Subjects considered to have eidetic imagery can typically answer detailed questions about previously seen pictures as if those pictures were still visible by knowingly referring to their memory of the picture (Richardson 1983, 23–26). Other terms, such as 'voluntary hallucination', also operated synonymously with eidetic imagery (Blom 2010, 541).

emergence

Emergence in this context is the notion that something can arise from the existing **conditions of possibility** without being determined by these conditions. For example, see Theodore R. Schatzki's (1999, 158) discussion of the ambiguities within the inter-connected – yet not interchangeable – notions of epistemological and ontological emergence that support Pickering's '**mangle**' account of scientific practice.

For a discussion of philosophical considerations of the way the term *emergence* is used in relation to science, see (Mitchell 2012). Also see the collection of works edited by Mark A. Bedau and Paul Humphreys (2008) for a discussion of the epistemological and ontological questions of *emergent phenomena* in philosophy of science.

emotional-valence

Emotional-valence is one of the dimensions of an individual's emotional response to an event of a given experience. While often taken for granted, the notion of emotional-valence as a measure of 'negative' and 'positive' responses has also been challenged by the closer attention to individual emotions and the overlapping dimensions by which emotional-valence can be assessed (de Sousa 2014).

empiricist philosophical tradition

The details of this tradition are outside the present scope. For the ways in which I understand the impact of this tradition on the intersecting development of the concepts of **mental imagery** and **hallucinations,** see the **mediator-view of SLMP.**

endogenous

Within biology, if something is endogenous it originates from within the organism. Within the present context, I am considering **SLMP** to be endogenous if they are not induced by external factors (such as psychedelics, pharmaceuticals, isolation, sensory-deprivation, sleep deprivation, acquired brain injuries, and so on). Compare: **exogeneous.**

epistemic goal

I am following others in using the term epistemic goal for any goal that pertain to generating knowledge (Brigandt 2012, 78; Steinle 2012, 107; MacLeod 2012, 68). Within this context, epistemic goals can be considered those that pertain to knowledge whether they are specific to a discipline (such as the goal of explaining cell-cell interaction in cell-biology as Brigandt describes) or to the collection of phenomena investigated (such as the goal of finding a regularity that predict the behaviour of a type of phenomena (such as the attraction/repulsion regularity that, once conceptualised as bipolarity, was able to predict the behaviour of electrically charged objects that Steinle (2006) describes). When it comes to investigating phenomena, the knowledge sought is often intended to 'make sense of' the phenomena within a given domain of knowledge in some way (such as the classification, quantification, or explanation of the phenomena in relation to that domain).

exogenous

Within biology, if something is exogenous it originates from outside an organism. Within the present context, I am not including any exogenous SLMP in my analysis; only those that can be considered endogenous. Compare: **endogenous**

experimental investigations

Despite the common view of experiments as procedures for testing hypothesis within philosophy, there is an older tradition of viewing any empirical observation as experiments (Mautner 2005). Within philosophical accounts of the sciences *as practiced*, this view of experiments as empirical observation has been developed to take into account those experimental practices that intervene in the phenomena under investigation (e.g., Hacking 1983). Within this context, the phrase *experimental investigation* is used to highlight that experiments are dynamic practices. In using it I intend to include multiple types of experiments – including both hypothesis-testing experiments and exploratory experiments. While these variations are beyond the present scope, it is worth noting that there have been multiple accounts of 'exploratory experiments' (e.g., Burian 1997, 2013; Steinle 1997, 2016).

In this context, I am drawing on Steinle's (2016, 319) description of exploratory experiments as those that involve multiple individual experiments that "typically aim at the level of laws, and sometimes that of concepts, but not of theories". In contrast to this approach, my research focuses on individual experimental investigations as such, I will avoid talking about exploratory experiments (focusing, where relevant, on **exploratory aims** instead).

exploratory aims

In Chapter Seven I use the term 'exploratory aims' to highlight those aims that are articulated within *individual* **experimental investigations** that seek to gather data on potential correlations, develop new techniques, and resolve anomalies at an experimental level (rather than test a hypothesis). Broadly speaking, these experiments can be considered exploratory in the sense described by Richard Burian (2013). However, my analyses provide no indication as to whether these individual experiments contribute to exploratory experiments (plural) in the more specific sense described by Steinle (1997, 2010b, 2016). For Steinle, it is through these multiple experimental investigations that fundamental concepts are revised; not individual experiments. As detailed in Chapter Eight, my research demonstrates ways in which scientific concepts resist revision within individual experimental investigations (in line with Steinle's account). However, as I only examined individual experimental investigations, I have nothing to add to the broader discussion of exploratory experiments. Given my focus, I have avoided the use of the term exploratory experiments in favour of 'exploratory aims'.

fMRI (functional magnetic resonance imaging)

This non-invasive neuroimaging technique uses MRI machines to indirectly observe changes in **neural activity** in the human brain over time. Introductory summaries can be found in fMRI training manuals (Bandettini and Moonen 2000; Filippi 2009) while further explanations can be found in introductions to MRI machines such as (Smith and Lange 1998). Also, see William Bechtel and Richard C. Richardson (2010) for a list of the principles of fMRI that can be regarded as commonly recognised by researchers (even when not made explicit in their publications).

Note that, to use this fMRI data to investigate the neural **mechanism** involved in mental processes, various experimental conditions are designed to isolate specific mental processes and establish a specific brain-behaviour correlation. That is, a correlation between: a) the mental processes isolated by the behaviour during the experimental condition; and, b) the change in **neural activity** measured during the experimental condition. For example, see: **SLMP-neuroanatomical-correlates**.

hallucinations

Mental experiences of sensation that have a compelling sense of perception despite the absence of relevant sensory stimulation (Blom 2010; Farkas 2013; Jardri and Sommer 2013; Peyroux and Franck 2013; Shine et al. 2011; Stephane 2013). Of these, I am interested in **endogenous** hallucinatory experiences that occur while conscious and in the waking state (in any sensory modality). In the present context, I am analysing these as a form of **SLMP**.

broader uses of 'hallucinations':

There are broader uses of the concept of hallucinations that I will not consider. For example, the in some contexts 'hallucinations' include those sensory-like experiences that occur during altered states of consciousness such as hypnogogic and hypnopompic experiences related to sleep, and those experiences induced by external conditions such drugs, isolation, sleep deprivation. For discussions of various types hallucinations see Jan Dirk Blom (2010).

Also note that as part of these broader uses, some forms of **mental imagery** are sometimes categorised as types of hallucinations while some forms of hallucinations are sometimes categorised as types of imagery: for an for example of the former see (Macpherson 2013b, 23–24), for debates over the latter see (McGinn 2004; N. J. T. Thomas 2014a). However, I am interested in the narrower uses of these concepts within scientific experiments that use each concept independently of the other to investigate conscious experiences of mental imagery or endogenous hallucinations. As such, I will leave these additional layers of conceptual ambiguity aside as much as possible.

pre-history of the concept and term 'hallucinations'

The term hallucinations is derived from the Latin *allucinari* or *allucinatio* (to wander mentally) which has its root in the Greek *aluein* (to be distraught, or to wander) – neither of which connote errors of perceptual misattribution (André Aleman and Larøi 2008, 12; Blom 2010, 219). However, in a tract discussing madness in the sixteenth-century, Ludwig Lavater's *De spectris, lemuribus et magis* used *allucinatio* synonymously with *illusio*, to refer to the mental condition of entertaining unfounded notions to which nothing real corresponds (T R Sarbin and Juhasz 1967, 345). When translated into English in 1572, Lavater's use was anglicised as 'hallucination' and became the term used for apparitions such as ghosts, spirits, strange noises, and forewarnings (T R Sarbin and Juhasz 1967, 345). Similarly, an eighteenth-century nosology of disease described hallucinations as a form of 'suffusion' whereby a defect of the imagination lead to an error of judgement where something is seen when it is not actually present (Boissier de la Croix de Sauvages 1785, 238–39). Cases of 'suffusion' were distinguished from delusions in that the latter indicated as an intractable defect of the brain, while the former indicated merely a defect of the external sense organs, easily corrected with the help of other senses (Boissier de la Croix de Sauvages 1785, 240). Using the term in a similar way when formally introducing it into the English medical vocabulary, Sir Alexander Crichton listed the term hallucinations as interchangeable with that of the term illusion (T R Sarbin and Juhasz 1967, 347). As such, within his outline of the numerous genera of neuroses, Crichton (1798, Volume 2:342–43) lists "Hallucinatio, or 'Illusion [as an] Error of mind, in which ideal objects are mistaken for realities; or, in which real objects are falsely represented, without general derangement of the mental faculties".28F[205] Indeed, up until the early nineteenth-century an hallucination could refer to anything from an error in judgement or foolish behaviour to illusions and false beliefs (Bailey 1731; Chapman 1743, 307; Ferriar 1813, 95–96). Indeed, John Ferriar (1813, 96) took special note to include the experience of lycanthropy (the belief that one can shape-shift between human and animal form, an experience most commonly associated with the myths of werewolves) under the definition of hallucinations.

In addition to the variable use of the term hallucination during this time, eighteenth-century disease classificatory lists included numerous descriptions redolent of contemporary understandings of hallucinations (Berrios and Marková 2012, 57). For example, W. Battie (1758, 5–6) regarded 'deluded imagination' to be "the perception of objects not really existing or not really corresponding to the senses [and] a certain sign of madness". Whereas, the definition of 'sensitive insanity' by T. Arnold (1782, 158) described "erroneous images which are excited in the mind, relative to the person's own form".

hallucinations vs illusions

Also note that if the confusion between the mental experience and reality incorporates a distortion of a perceptual stimulus then the experience is generally characterised as an illusion rather than a hallucinatory experience (Holt 1964, 235). However, in cases where delusions are linked to the confusion between the mental experience and reality this distinction is not

[205] Note that, Hallucinatio/ Illusion was listed as the second genera of the order *Vesaniæ* in the classification *Neuroses.* (Crichton 1798, Volume 2:342–43)

necessarily made, with distorted perceptions and quasi-perceptions contributing to the content of a delusion. Likewise, I am treating hallucinations as distinct from the misinterpretations of most 'sensory errors' (such as illusions and misperceptions). See William Harris (2013, 286) for some convenient examples of the difference between hallucinations and sensory errors as these relate to examining historical accounts of hallucinations prior to the nineteenth-century.

types of hallucinations

As with **mental imagery**, hallucinations are often considered in terms of the modality of sensation that is experienced as SLMP. While hallucinations can occur in any sensory modality, and mixed-modality hallucinations also occur, the most commonly investigated type are **AVH** (auditory-verbal hallucinations).

clinically-relevant hallucinations

See Chapter 3, Tables 2 and 3.

non-pathological hallucinations

See Chapter 3, Tables 2 and 3.

hearing-voices

Hearing-voices (i.e., the experience of 'hearing' voices) are also referred to as voice-hearing experiences. These phrases are often used to avoid the term **hallucinations** due to its role in stigmatizing people who experience auditory-verbal SLMP. Therefore, although 'hearing-voices' and **AVH** are often used interchangeably, the concept of 'hearing-voices' is increasingly used for a wider range of auditory-verbal SLMP than would traditionally be considered pathological hallucinations (further blurring the distinctions between the concept of hallucinations and those such as pseudohallucinations, non-pathological hallucinations). Although beyond the present scope, it would be interesting to explore the role of the concept of 'hearing-voices' – as distinct from **AVH**s – in recent research into the role of factors other than SLMP in the distress associated with voice-hearing experiences. For examples, see (Andrew, Gray, and Snowden 2008; Beavan and Read 2010; Longden, Madill, and Waterman 2012; Sanjuán, Moltó, and Tolosa 2013, 234).

HPS

Typically, the field of History and Philosophy of Science but also used for historical and philosophical studies of the sciences more broadly. Within the broader context of historical, philosophical, and social studies of the sciences, I use HPS is used to indicate an amalgamation of overlapping research approaches that, although having contested boundaries, coalesce around research that examines historical and/or philosophical questions about the sciences. In terms of the sciences studied, these include any of the experimental sciences as well as various applied scientific fields such as medicine and engineering. As a field, HPS has long operated as a self-conscious link between discrete approaches investigating historical or philosophical questions about science (Ellis et al. 2014; Giere 2012; Schickore 2011). However, the integration of historical and philosophical studies of science is increasingly considered valuable (Chang 2012a; Steinle and Burian 2002). As discussed in Chapter One, there is significant overlap between **STS** and integrated HPS approaches to studying **scientific practices**.

IFG (inferior frontal gyrus)

The IFG is a **neuroanatomical region** of the brain located in the anterior convolution (gyrus) of the frontal lobe and often investigated as a region of interest (**ROI**) in **fMRI** experiments. The IFG consists of three parts of the anterior portion of the frontal lobe: the *pars orbitalis,* the *pars triangularis* and the *pars opercularis* (Duvernoy 1991, 6–7, 2012, 8–9). Together, the *pars triangularis* (BA45) and the *pars opercularis* (BA44) form the *frontal operculum* (Bowden 2015; Duvernoy 1991, 6–7, 2012, 8–9). In the dominant hemisphere, the *frontal operculum* is where the functional region associated with the production of language (*Broca's area*) is located (Nolte and Angevine 2013, 225). In addition to BA44 (*pars opercularis*) and BA45 (*pars triangularis)*, the IFG also incorporates parts of a number of the other Brodmann areas (Clarkson, Rosse, and Mejino 2015). Of these, BA46 includes the most anterior part of the IFG, BA47 extends laterally from the orbital sulci into the orbital part of the IFG, and BA9 includes the area in the inferior frontal sulcus that bounds the IFG. Note that the BA46 also forms the central third of the MFG region. Also, parts of other Brodmann areas, such as BA6, BA10, BA11, and BA25, are also sometimes included within the IFG despite being more closely aligned with other structural landmarks. For example, BA10 is broadly aligned with the composite substructure known as the transverse frontopolar gyri that marks the boundary between the frontal and orbital lobes (Bowden 2015). However, while BA10 is medial to the IFG it is usually considered a separate area. Therefore, these regions have been excluded from what is being regarded as the IFG in this analysis.

imageless-thought debates

Occurring during the early 20th century this debate was between two incompatible positions on the role of **mental imagery** in thought: 1) the view that all thought *requires* imagery; 2) the view that not only does thought not *require* imagery, these sensations are undesirable.

Both views had stronger and weaker versions:

- In the first case, the moderate claim positions imagery as the foundational building blocks of thought which may or may not be experienced as part of all thought; the stronger claim positions all thought as involving either sensation or the images of sensation (Bower 1984). Both of these contribute to the **mediator view of SLMP** and neither take into account the large minority of who report a range of diverse image-free ways of thinking (Betts 1909), including experiences attributed to being a non-imager (Faw 1997, 2009).
- In the second case, there was the moderate claim that imageless thought operates alongside image-based thoughts; and the stronger claim that imageless thought is the most exemplary form of thinking (Angell 1911, 296–97). Note that there was some confusion around this distinction. For example, Angell (1911, 296–97) regards E.B. Titchener (1909b) as providing an example of the weaker claim which was frequently mistakenly cited in favour of the stronger claim.

imagery / images

The term 'image' (to mean any reproduction of something) is distinct from that of 'mental image' although the latter is nonetheless shortened to 'image' when the meaning is clear.

imagination

As Mathew MacKisack (2016, 4) points out, a distinction is now recognised between imagining such-and-such as an image and the propositional imagining *that* such-and-such is the case. This distinction is not a new one. For example, Bachelard shifted from viewing imagination as going no further than sensation (in the 1930s0, to recognising (during the 1940s) that, while we often assume imagination depends on sensory activity, this is an etymological confusion – the terms **image** and imagination mean quite different things (Kotowicz 2018, 86).

imagination-imagery

A form of **mental imagery**, imagination-imagery involves the construction of sensory-likenesses in novel ways. Descriptions of the copies of perception from which imagination-imagery are constructed typically imply the use of memory-images. Less studied then **memory-imagery**, a classic study in the field is still Perky's (1910) ground-breaking work questioning the presumed ability to distinguish the functional relationship between perceived and imagined stimuli.

individuate

To individuate something is to single it out by distinguishing it from others of the same (broader) kind. I have adopted this term as it relates to the use of concept as tools from Uljana Feest. As discussed in Chapter One, Feest (2010, 173) describes **scientific concepts** as individuating a type of phenomena for further investigation by delineating the class of phenomenon of interest from other types of phenomena within an available body of knowledge. As Corinne Bloch (2012a, 215) highlights, this process of individuation involves articulating the **characteristics** of the phenomena of interest Similarly, Ingo Brigandt (2010, 25) argues the basis for such concept individuation can be based on any combination of a concept's referential role, inferential role, and/or epistemic goal.

inner-speech

What counts as 'inner-speech' varies: it is considered synonymous with the generation and monitoring of 'verbal imagery' (Vercammen et al. 2011, 1009); described as incorporating classes of both auditory imagery of speech and silent articulations of speech (Hubbard 2013b, 231); or specifically defined as the generation of non-sensory 'silent articulations' of speech (Fernyhough and McCarthy-Jones 2013, 94). On those occasions when inner-speech and mental imagery are distinguished without subsuming the latter within the former, it is usually to clarify that 'inner-speech' lacks the sensory-like qualities of auditory-verbal imagery (AVI). For example, inner-speech has been described as the silent generation of an 'inner voice' in contrast to descriptions of AVI as requiring the generation and monitoring or inspection of a remembered voice as if it was 'heard' (McGuire et al. 1995, 598, 1996, 29). At the same time, although the inclusion of AVI within the definitions of inner-speech might be noted, the distinction of interest is still that **AVH** have a "distinct 'auditory' quality quite unlike normal inner speech" (Ford and Hoffman 2013, 361). Compare: **mental imagery**

IPL (inferior parietal lobe/lobule)

The IPL is a **neuroanatomical region** of the brain and often investigated as a region of interest (**ROI**) in **fMRI** experiments. Located in the dorsal-posterior portion of each hemisphere, the IPL encompasses two major sub-regions that are frequently delineated: the more anterior supramarginal gyrus (BA40) and the angular gyrus (BA39) at the posterior of the region (Bowden 2015; Clarkson, Rosse, and Mejino 2015; Siegel et al. 2008). A large region, **neural activity** within the IPL is considered important for, among other things, goal directed movement and the integration of different sensory stimuli (Tuleya 2007; Siegel et al. 2008). In relation to these associations, the IPL is also incorporated within several functional regions and networks. For example, the IPL is considered a key region within the default mode network (DMN) (Broyd et al. 2009). Another example that is discussed in some of articles considered is the temporoparietal junction (TPJ) which is described as incorporating part of the IPL (the angular gyrus) along with the caudal STG to incorporate an area associated with both information processing and perception(Vercammen et al. 2010, 915). In addition, while Wernicke's region is typically located within the STG as discussed, broader definitions of this language region extend the area into the IPL (Anthoney 1994, 587). Given this variability, I have not considered reports of activity within Wernicke's region to incorporate the IPL unless explicitly stated.

knowledge-claims

I have used knowledge-claims as short-hand for *first-order* knowledge claims. There are other types of knowledge-claims that are beyond the scope of this thesis. In this context, (first-order*)* knowledge claims can be understood as providing 'unit contributions…of scientific development' that – if incorporated into the structure of the relevant scientific discipline – can become accepted as scientific facts (Leydesdorff 1991, 75). See Chapter One and Five for more detail.

mangle of practice

The 'mangle' of scientific practice is a term specific to Pickering (1995b, 105), who describes the "dialectic of resistance and accommodation [called] the mangle of practice" as an emergent 'mangle' of unpredictable extensions and interactions between both human and nonhuman aspects of scientific practice. See Chapter One for more detail.

material agency

A form of **agency** that can be understood as the forces of the material world that produce specific effects on the world (Pickering 1995b, 23). I discuss differing approaches to the notion of material agency from accounts of technoscientific practices in Chapter One. For a more philosophically focused discussion of the notion of material agency (as the relational and asymmetrical actions of co-constituted material entities) see (Kirchhoff 2009).

mechanism (explanatory mechanism)

As Feest (2012, 2014) notes, instances of phenomena are **individuated** for **experimental investigations** into a given object of research in ways that can function as evidence (for a related object of research) as well as the explananda of mechanistic explanations. In the case of experiments that use the concepts of either mental imagery or hallucinations – whether as **objects of research** themselves, or within the broader cluster of phenomena that formed the object of research – instances of **SLMP** are sometimes investigated purely for descriptive purposes and sometimes for identifying *causal* mechanistic explanations of the object of research. In these cases, the cause proposed is typically a pathway that, at a **neurophysiological** level, is proposed to explain the SLMP in question (or the role of SLMP in the broader object of research).

In the latter case, I am using mechanism as short for 'explanatory mechanism' – specifically, the causal neurophysiological processes sometimes proposed to explain the mental phenomena in question. For a discussion on the historical context for the various uses of the concept of 'mechanism' in biology, see (D. J. Nicholson 2012). For a discussion on how mechanism-focused experimental approach relates to other approaches in the philosophy of biology, see (Darden 2008, 958–59). For some discussion of non-mechanist investigations within scientific practice see (Colaço et al. 2015).

When it comes to investigating mechanisms within the biological sciences, a satisfactory explanation for a given type of phenomena requires a description of the mechanisms responsible for that type of phenomena (Machamer, Darden, and Craver 2000). In relation to this view of scientific explanation, Craver and Darden (2013, 56) have argued that "the characterisation of phenomena are critical for thinking about the mechanisms that might possibly explain [that phenomena]". For example, Darden (2008, 960) has emphasised that the relationship between characterising phenomena and identifying the mechanisms for that type of phenomena are open to revision within experimental practice.

This recalls accounts of scientific investigations by Feest, Bloch, and Brigandt that describe the characterisation of a concepts developing within the context of an available **body of knowledge** to individuate instances of specific type of phenomena so that the concept can then be used to investigate this type of phenomena further. In this light, when neurophysiological processes are presented as an explanatory mechanism for the specific experience of a given type of SLMP, this is taken to include the entities (anatomical regions of the brain) and activities (change in neuronal activity within these regions during an experimental condition) that are indirectly measured with neuroimaging techniques. In this way, any **SLMP-neuroanatomical-correlates** can be taken as evidence for specific mechanisms that might explain either the functions mental imagery or dysfunctions responsible for hallucinations.

During this process, **scientific concepts** can be experimentally refined as various 'lumping' and 'splitting' errors can be identified Craver's (2007). Put another way, it is important to recognise that "the very question of what constitutes the relevant explanandum phenomenon can shift in the course of research…where accounts of phenomena at various levels are mutually adjusted to one another" (U. Feest 2012, 183). In the case of mental imagery and hallucinations in the experiments examined, the potential for identifying lumping and splitting errors were not developed. Instead, each concept was used as a stable tool that carried routine expectations about the type of mechanism that would (eventually) explain the type of SLMP that formed the object of research.

Insights such as these highlight the value in examining potential process of reconstituting phenomena within experimental practices as these offer another avenue for examining the unresolved question of whether the concepts of mental imagery and hallucinations refer to related forms of SLMP or not. I have not explored these insights because these practices of reconstituting the phenomena under investigation were not evident in the short time period captured by the experiments I examined.

mediating-role associations

This is a series of associations that justified (within the knowledge context of the nineteenth-century) the *strong* **mediator-views of SLMP**.

Despite the varieties of mediator-views all varieties of the mediator-view are based on a series of entrenched associations that makes most sense within the philosophical context of the strong versions of the mediator-view. In brief, these mediator-view associations position ordinary SLMP as able to safely mediate between sensations and thought if active and voluntary or, if passive, able to be controlled by rational judgement; such that a lack of control and/or a failure to regulate ordinary SLMP can therefore lead to confusion of SLMP for perception.

This series of associations rests on some key assumptions: 1) that ordinary SLMP are desirable; 2) that SLMP need to resemble perception enough to provide a mental representation that could serve as a sensory copy to aid abstract thought, but not enough that it might lead to confusion about perception; 3) that SLMP that are too similar to perception (vivid/forceful/persistent) are difficult to control; 4) that a lack of control over an image can make it difficult to regulate the SLMP though reasoned judgement; 5) that a failure of reason or judgement about an experience of SLMP is undesirable because it can lead to confusion as to the source of the SLMP (confusion of SLMP for perception); 6) and that this failure of reason or judgement is an individual problem due to physical or mental dysfunction;

mediator-views (of SLMP)

A term I am using for a range philosophical and psychological accounts of thought that each position ordinary **SLMP** as a mediator (of variable importance) between perceptions and thought. It is important to note that there was never a unified mediator view of SLMP (let alone a theory). The 'mediator view' is not a historical claim; rather it is a phrase offered merely as a rhetorical device to highlight the set of associations common to these diverse accounts of SLMP

There are two main varieties:

1. The 'strong' position, where ordinary SLMP are a *necessary* mediator between perception and abstract thought. This strong 'mediator-view' is particularly evident in the work of Aristotle. It is a key element in the British Empiricist philosophical tradition; of which a Hume was an influential example (Bower 1984; Roeckelein 2004, 149; Faw 2009, 6). Later implicit proponents include Titchener and, the even more recently, the 'strong-view' still features in the 'neo-empiricist' account of concepts as perceptual representations (philosophical debates around this view of concepts have been examined elsewhere, see: (J. McCaffrey and Machery 2012, 270–73; Bloch-Mullins 2015, 944–49)).

2. The 'weak' position is more variable. Typically, views of thought are presented that hold that ordinary SLMP *can* act as a mediator between perceptions and thoughts-about-

sensations but are *not required* for abstract thought. Examples of this weaker view are evident in the proponents of 'imageless thought'. For an account of the historical development of the concept of mental imagery that emphasises the developments between the foundational views of the mediator-view (the so called iconophiles) and their intermittent challengers (the so called iconophobes), see (MacKisack et al. 2016).

In both varieties, ordinary SLMP (**mental imagery**) are desirable because they can mediate between unruly sensations and the reasoned judgement of abstract thought; however, to ensure that they are not confused for real perception, these ordinary SLMP need to be regulated. It is when these regulatory processes fail (due to physical or mental dysfunction) that undesirable SMLP (such as divine visions, disturbed imaginations, and **hallucinations**) can occur. In this way, pathological SLMP are positioned as experiences of SLMP that result from a disruption of the mediating role of ordinary SLMP.

Despite the varieties of mediator-views all varieties of the mediator-view are based on a series of entrenched associations – see **mediator-view associations.**

memory-imagery

A type of **mental imagery.** In the case of memory-images, recorded accounts have been traced to the associative visual mnemonics used in ancient rhetorical methods (Paivio 1970, 385; Also see: Yates 1966). Another ancient account is provided by Plato's argument that perceptions and thoughts are remembered due to their image being temporarily impressed onto the mind 'as onto wax' (Paivio 1970, 385). These associative and 'memory-trace' accounts of memory-images were, to a large degree, taken for granted right up until the twentieth-century (Paivio 1970, 385).

mental imagery

Mental Imagery are those experiences of sensation that resemble perceptual experiences yet occur in the absence of the appropriate perceptual stimuli (Hubbard 2010, 302; N. J. T. Thomas 2016; Richardson 1993, 63). Of these, I am focusing on endogenous mental images that are experienced while conscious and in the waking state (in any sensory modality), which in this context are being analysed as a form of **SLMP**.

broader uses of 'mental imagery'

The term mental imagery is also used more broadly in a range of other contexts. For example, in some contexts, mental imagery (and **hallucinations**) are used broadly to include experiences that occur during altered states of consciousness including hypnogogic and hypnopompic experiences related to sleep and those experiences induced by external conditions such drugs, isolation, sleep deprivation. For an indication of the range of experiences conceptualised as mental imagery see the lists provided by Alan Richardson (1983, 1993, 115) and Jon E. Roeckelein (2004, 68–69). Furthermore, the term 'image' (to mean any reproduction of something, including mental imagery) is distinct from that of 'mental image' although the latter is nonetheless shortened to 'image' when the meaning is clear.

In addition to being used for both **endogenously** and **exogenously** generated forms of SLMP, the term mental imagery is sometimes used even more broadly in philosophical discussions: including for cognitive 'imaging-that' functions that are relational and do not necessarily rely on SLMP (Casey 2000; Gauker 2011). Similarly, some accounts of mental imagery also incorporate 'subliminal imaging' wherein individuals are presumed to generate imagery even though they don't consciously detect these representations of sensory perception (a view that rests largely on the assumption that certain tasks require mental imagery whether consciously or not) (Faw 2009, 20). These philosophical theories around the nature of ideas have often conflated the act of forming a mental image (imaging) with the process of creative innovation (imagining) (Theodore R. Sarbin and Juhasz 1970, 53). For example, Hume's distinction between the presence or absence of percept-like vivacity did not extend to vividness being held as an essential characteristic of either memory-images or imagined images (Brann 1991, 85–86). Nonetheless, the 'copy' thesis of mental images that it presents became an influential component of latter imagery-debates (Bower 1984, 217). Where, the tendency to conflate the concept of mental imagery with imagination (and, in different contexts, with memory) has led to a number of conceptual problems within cognitive science (Bennett and Hacker 2003, 183–86). While continuing to be conflated, a distinction is now generally recognised between imagining such-and-such using mental imagery and the propositional imagining *that* such-and-such is the case (MacKisack et al. 2016, 4).

Also note that as part of these broader uses, some forms of imagery are sometimes categorised as types of hallucinations while some forms of hallucinations are sometimes categorised as types of imagery: for an for example of the former see (Macpherson 2013b, 23–24), for debates over the latter see (McGinn 2004; N. J. T. Thomas 2014a). However, I am interested in the narrower uses of these concepts within scientific experiments that use each concept independently of the other to investigate conscious experiences of mental imagery or endogenous hallucinations. As such, I will leave these additional layers of conceptual ambiguity aside as much as possible.

types of mental imagery

There has been sporadic interest categorising the usefulness of **mental imagery** for memory in terms of dominant sensory modalities within a doctrine of 'imagery types' (Angell 1910, 63–67; Fernald 1912, 26). In this context, imagery types were defined primarily on the individual differences of reported vividness in the image remembered; relating accuracy of recall to higher degrees of image vividness (Paivio 1970, 386). Taken together, the results of these experiments were inconclusive (Paivio 1970, 386). Moreover these experiments assumed rather than tested imagery use – as such, while influential in education theory, experimental techniques for investigating mental imagery *per se* stagnated (Angell 1910, 63–67).

fallow period in mental imagery research

A period between the 1930s and 1960s when little experimental research was published on the topic of **mental imagery**.

A range of interconnected factors have been suggested for this fallow period in the history of mental imagery research: the shift towards behaviourism within psychology; a loss of methodological confidence in introspection; the influence of the turn towards language as the basis of thought within analytic philosophy; and the increased scepticism over the reality of quasi-perceptual experiences in within the philosophical Phenomenology (Kind 2001, 85–86; Joel Pearson 2014, 178–79).

Whatever the dynamics of these broader influences, they converged in such a way that experimental approaches within English-speaking psychological discourse took little interest in experiences of SLMP (Hebb 1968, 737; Holt 1964, 257; S. M. Kosslyn, Behrmann, and Jeannerod 1995, 1336; MacKisack et al. 2016).

mental process (mental state)

In this context, mental process can be taken to be either those processes that occur during a mental state (such as experiencing **SLMP**), or those processes considered responsible for predisposing a specific mental state experience (such as **SLMP**).

metacognition

In this context, metacognition refers to the introspective processes that individuals employ to monitor and control their thoughts (Varese and Larøi 2013, 154).

MFG (middle frontal gyrus)

The MFG is a neuroanatomical region of the brain that is often investigated as a region of interest (**ROI**) in **fMRI** experiments. It consists of the central of the three longitudinally orientated gyri (convolutions) in the frontal lobe. Laying just above the IFG region, the MFG is the central of the three longitudinally orientated gyri in the frontal lobe (Nolte and Angevine 2013, 231). The most common subdivisions of the MFG differentiate between the superior and inferior part of this gyrus (Duvernoy 1991, 6). In addition, as the largest of the frontal gyri, further divisions often specify the polar, anterior, middle, and posterior parts of the MFG (Clarkson, Rosse, and Mejino 2015). Likewise, as with the other ROI discussed, several Brodmann areas (BA) fall within with the MFG. Of these, BA9 & BA10 are firmly located within the MFG (Bernal and Perdomo 2008). In addition, BA46 extends into the anterior part of the MFG, while BA6 extends into the posterior end of the MFG (Bernal and Perdomo 2008). In humans, the BA6 is also closely associated with the functional region known as the *frontal eye field* (Nolte and Angevine 2013, 231; Vernet et al. 2014).[206] Other functional regions that are sometimes partially located within the MFG are the BA4, BA8, BA11, BA25, BA32, and BA47 (Clarkson, Rosse, and Mejino 2015). However, of these, only BA8 was reported as part of the MFG in the articles studied.

modality / modalities

The modality of a sensation (or modalities of sensory perception) refer to the mode of perception the sensation occurs in response to: visual, auditory, tactile, gustatory, olfactory, or kinaesthetic. Likewise, the modality of an experience of **SLMP** refers to the mode(s) of perception the SLMP 'feels' like: visual, auditory, tactile, gustatory, olfactory, or kinaesthetic.

multi-method

Sometimes used synonymously with mixed methods, the term 'multi-method' is intended to indicate that I collected data that included both numerical and non-numerical variables which

[206] Note that, the primate frontal eye field - "defined physiologically as the portion of the dorsolateral prefrontal cortex from which low-intensity intracortical stimulation is able to elicit rapid eye movements" – has been located within BA6 in humans and within BA8 in non-human primates (Vernet et al. 2014).

were analysed using both quantitative and qualitative approaches (Vogt and Johnson 2016, 270).

neural activity

The electrical and/or metabolic activity of neurons (cells in the nervous system), that can be measured as an increase of decreases in a specified brain region relative to baseline.

neuroanatomical correlates

The changes in **neural activity** within localised neuroanatomical regions that, when measured with neuroimaging techniques, correlate with a given behaviour or mental phenomena ('X'). Within the present context, 'X' is an experience of **SLMP** (conceptualised as either **mental imagery** or **hallucinations**). The reliability of these neuroanatomical correlates depends on specific experimental condition intended to isolate the type of phenomena conceptualised. In addition, this notion that it is possible to identify the neuroanatomical correlates of a given mental phenomena presupposes that it is possible to locate the anatomical region(s) of the brain within which neuronal activity manifests in a way that corresponds with the mental processes the test-subject is experiencing. For a discussion of the different approaches taken to the localisation of function and the position of such approaches within the stratification of various neuroscientific goals, see (Mundale 2001, 48).

neurocognition

Neurocognition (and related terms) can be taken to refer to "the **neurophysiological** bases underlying cognitive functions" (Tuleya, 2007, p. 194). In line with this, neurocognitive processes are those functional neurophysiological processes (ordinary/functional neurocognition) that, if disrupted, can result in the dysfunctional neurophysiological processes that underlie neurocognitive disorders.

neuroimaging

Neuroimaging involves techniques that provide images that represent structural and/or functional aspects of the brain. Structural neuroimaging provides a representation of the structural composition of tissue (e.g. MRI). Functional neuroimaging indirectly measures localised changes in brain activity via changes a range of including electrical activity (e.g., EEG) and blood flow (e.g., **fMRI**), or some other measure.

neurophysiological processes

Here the term 'neurophysiological processes' is used to refer to the physiological processes and structures of the nervous system (Tuleya 2007, 195). In relation to this, it is worth noting that I will be focusing on the structures and processes in the cortex of the brain rather than the nervous system more broadly. Accounts of the underlying neurophysiological processes that might explain mental experiences conceptualised as either **mental imagery** or **hallucinations** are typically proposed based on findings of **SLMP-neuroanatomical-correlates**.

neurophysiology

Following Tyleya (2007, p.195) I am using neurophysiology to refer to the "physiology of the nervous system" including both neurophysiological structures and **neurophysiological processes** (and the study of these).

neurosciences

Following Tyleya (2007, p.195-196) the neurosciences are those scientific disciplines "concerned with the development, structure, function, chemistry, and pathology of the nervous system" – including neuroanatomy, neurobiology, neurochemistry, neurology, neuropathology, neurophysiology, neuropsychiatry, and neuropsychology.

nonhuman

Within the **STS** discourse discussed, nonhumans are those **actants** that cannot speak for themselves – including a range of material, biological, and incorporeal entities (Ihde and Selinger 2003). It remains a contested term (Jensen 2003a, 88; Stengers 2010). However, for the present purposes it provides a convenient short-hand for the wide range of heterogeneous **actants** that have been described as collaborating with humans in the performative construction of **scientific knowledge**.

non-imagers

I have adopted Bill Faw's (1997, 2009) use of 'non-imagers' for people who are able to think without relying on **mental imagery** in any sensory **modality**. While experiences of thinking image-free are as varied as those involving imagery, differentiating between experiences of thinking that involve imagery or not helps to challenge the common assumption that everyone thinks the same. In relation to this, it is worth noting the recently coined term 'aphantasia' in increasingly used to describe not experiencing *visual* imagery (Zeman, Dewar, and Della Sala 2015). Although perpetuating and etymological confusion by conflating the imagined object (**imagery**) with the process of **imagination** itself, this term 'aphantasia' has been taken up by researchers interested investigating the diversity of individual experiences of thinking (e.g., Keogh and Pearson 2017). It would be interesting to study the popularity of the concept of 'aphantasia' as a *lack* of a normal ability, compared to 'non-imager' as an identifier for a minority who have ways of thinking that differ from the majority. While beyond the present scope, the emphasis in discussion of 'aphantasia' on the 'lack' of *visual* mental imagery continues the trend, detailed in Chapter Four, of regarding visual SLMP as ordinary – and potentially necessary – elements of neurocognition. Regardless of the term used, if we are to learn anything from the history of mental imagery, articulating a concept for a group of people who think ways that does require imagery will overlook considerable individual variability.

neuroscientifically relevant psychological (NRP) factors

Without adopting this term, it is worth mentioning given the relevance of my research to ongoing discussion around the conceptual challenges faced by neuroscientists mentioned in my introduction and conclusion (Abend 2016; Bunzl, Hanson, and Poldrack 2010; Lenartowicz et al. 2010; Poldrack and Yarkoni 2016). Contributing to these discussions, are ongoing debates about the relevance of current ontological categories used in psychology to robust neuroscientific practices (Wright 2018). It is within this context that, Anderson (2015) argues that neuroscience has not zeroed in on 'neuroscientifically relevant psychological (NRP) factors'; a position supported by 1) the observed multi-functionality of parts of the brain, and 2) results showing that cognitive categories are not discriminable on the basis of neural data.

objects of research

Feest (2014, 1167) suggests that the 'objects of research' in (neuro)psychological experiments are often 'epistemically blurry' research targets; targets that are presumed to consist of (clusters of) phenomena that are independent of the conceptualisations used to tentatively individuate instances of these phenomena for further investigation.

In relation to this, I found that **SLMP** were investigated both as objects of research themselves, and as a specific type of **phenomena** relevant to the broader cluster of phenomena that formed the object of research. Put simply, while SLMP can become objects of research, they need not. As such, I have not explicated this distinction in my analysis. However, it is worth noting that this distinction would become important in the context of discussions around the role of concepts in the development of theory. For example, types of SLMP thought to occur in specific circumstances (such as either ordinary thinking or disordered thinking) are conceptualised (as either mental imagery or hallucinations respectively) based on characteristics thought to individuate instances of SLMP for further investigation. In these investigations, the respective types of SLMP may form the epistemically blurry object of research requiring further description and/or **mechanistic explanations**. However, mental imagery and hallucinations are also used in experiments as stable concepts for investigating specific types of SLMP with the goal of describing or explaining other, equally epistemically blurry, **objects of research** (such as memory, imagination, and various psychiatric diseases).

objectivity

Scientific objectivity is often positioned as an ideal of an ahistorical and universal view-from-nowhere that is unbiased, neutral, and dispassionate impartiality. However, in Chapter one I adopt an alternative view, common within the literature I draw upon, where context, scientific objectivity is taken to be the notion that **scientific knowledge** provides robust and intersubjective accounts of reality (that exists independently of human access to it and is distinct from human perspectives of it). For some historical context for the changing ideals associated with scientific 'objectivity', see (Daston and Galison 2007).

operational definition

I am following Feest's (2010, 177, 2016, 37) use of 'operational definitions' and am only interested in these regard to the *uses* of concepts. It is of course related to the broader debates around theories of concept meaning within the philosophical and psychological literature, however these are beyond the present scope (Chang 2009; J. (Uljana) Feest 2003).

For Feest (2012, 178), operational definitions articulate the paradigmatic conditions for applying a given **scientific concept** in practice without exhausting the meaning of the defined concept. In doing so, operational definitions carry empirical presuppositions about the phenomena purported in the extension of the concept. These empirical presuppositions structure the kinds of experimental interventions performed by articulating the typical conditions of application for the concept in question. In doing so, operational definitions function to specify the paradigmatic conditions for the application of the concept in ways that allow the concept to be used as a data-generating tool.

While Feest (2012) extends this approach to explore how concept formation and theory construction are intertwined within experimental practices, this was beyond the present scope. Suffice to say, that I found **mental imagery** and **hallucinations** to both be used as fully-formed concepts that functioned as stable tools even in theoretically-polyvalent experimental contexts. As such, my focus was on stable concepts; an approach that helps to highlight how operational definitions – and their corresponding concepts – are constrained by the body of knowledge about the complex interplay of mechanisms within a given domain (U. Feest 2012).

ordinary SLMP

Experiences of SLMP that are considered an ordinary element of the way that most people recall/imagine/re-experience sensory-based information (e.g., **mental imagery)**.

percept

A percept is a specific instance of perceptual experience (perception).

phantom perceptions

Pearson and Westbrook's (2015) notion of phantom perceptions provides an analytic category that includes both **mental imagery** and **hallucinations** (as well as a range of other experiences). While this notion clearly intersects with my notion of **SLMP**, there are some key differences. On the one hand, phantom perceptions provide a valuable way of analysing the intersections between research into mental imagery, hallucinations, illusions, synaesthesia, and other internally-generated percept-like experiences in the visual modality. In comparison, SLMP provides a category that is both more specific (excluding perceptual distortions such as illusions) and more general (incorporating all sensory modalities). As such, I have taken phantom perceptions as an analytic category for visual mental imagery (ordinary and intrusive), visual hallucinations (clinical and non-clinical) as well as experiences where visual perception and visual SLMP interact in unknown ways (such as 'perceptual filling-in' and synaesthesia).

phenomenon

A phenomenon can be taken in the strong sense (as a stable feature of the world that has repeatable characteristics), or in the weaker sense (as a repeatable characteristic that occurs under specific circumstances). In either case, claims about such phenomena can be either entailed by a theory and/or confirmed by experimentally generated data (J. (Uljana) Feest 2003). Of these, I am more interested in the latter. It is in relation to this that I explore the uses of concepts for individuating instances of types of phenomena in ways that can generate data in experiments (independently of the role of these concepts in theories).

Therefore, for the purposes of this thesis, I follow Uljana Feest (2014, 1169–12170) in taking the more restricted approach and treating 'phenomena' as those events that have characteristics that occur regularly under specific circumstances. For example, the concepts of mental imagery and hallucinations are used to individuate instances of specific types of SLMP based on those repeatable characteristics thought to occur under specific circumstances (such as either ordinary thinking or disordered thinking) even though it is not yet clear if these conceptualisations correspond to stable features of the world that have genuinely repeatable characteristics (i.e., healthy, and pathological forms of SLMP). See also: **objects of research** and **mechanisms**

phenomenological characteristics

See: characteristics, and phenomenology

phenomenal properties

See: characteristics

phenomenology

Unless otherwise stated, phenomenology refers to the study of first-hand reports of a conscious experience of a given type of phenomena (i.e., the subjectively reported experiential **characteristics** of a given type of phenomena). The phenomenological study of a given experience of SLMP focuses on investigating the subjective accounts of the experiential **characteristics** of that experience. For example, the phenomenological **characteristics** of SLMP are studied by examining first-hand reports of a conscious experience of SLMP (i.e., the subjectively reported **characteristics** of the SLMP experience). This is a broader use of the term then that used in the philosophical tradition of Phenomenology. For more on the phenomenological methods as used within psychology, see (Wertz 2015).

pseudohallucinations

The term pseudohallucinations and its variants are used for a wide range of experiences of SLMP that do not fit the typical **characteristics** of either mental imagery or hallucinations. In Chapter Four I outline two of the more influential concepts of pseudohallucinations, by Jaspers and Goldstein. However, it is worth noting that Jaspers and Goldstein both draw on earlier work, such as that of Victor Kandinsky which was influenced in turn by earlier work by within the French tradition (Berrios and Dening 1996; Walker 2013, 84). Both were Jaspers and Goldstein were influential, to different extents, within the German-language, Anglo-American, and British-English discourses (Berrios 1996, 49; Walker 2013, 83; F. K. Taylor 1981, 265).

realism

In this context, realism is an account of **scientific knowledge** that is typically contrasted with the opposing anti-realist account. Realist accounts continue to be of interest of philosophers of science (e.g., Chakravartty and Fraassen 2018; Sankey 2018). However, traditional questions about realism rarely feature in philosophical studies of the science *as practiced*. Furthermore, when realism is mentioned in the literature I build upon, the goal tends to be either reframing (Chang 2018) or side-stepping (Rouse 2018) realist/antirealist debates. Within the broader historical, philosophical, and social studies of the sciences, realist accounts of scientific knowledge are often contrasted with *relativistic* accounts of scientific knowledge. Once again, within the context of historical, philosophical, and social studies of scientific practices, the realism/relativism debates are typically being abandoned in favour of a range of views – including entity realism, pragmatic realism, and agential realism – that provide a view of **contingent yet objective scientific knowledges.**

realism/ relativism debates

For overviews, see the Stanford Encyclopaedia of Philosophy entries on scientific realism (Chakravartty 2016) and relativism (Baghramian and Carter 2015, sec. 4.4.3 and 4.4.4).

The debates between various forms of scientific realism and relativism are beyond the present scope. Instead, I have focused on those approaches seeking to side-step the duality of these debates by focusing on **scientific practice**; emphasising the similarities in how diverse approaches avoid both the universalism of strict **realism** and the relativism of **social-constructionism**.

To this end, I have avoided the various terms offered for these 'middle-road' views. Some examples will illustrate why. Firstly, Pickering (1995b, 180–92) side-steps realism/relativism debates by proposing a form of 'pragmatic realism' – an approach that is distinct from correspondence realism, scepticism, social-constructionism, and even Hacking's 'entity realism' on which he draws. Meanwhile, although differing in the details, others have developed similar alternatives to the polarised realist and constructionist positions. For example, Barad (2007, chap. 4) develops a 'agential realism' framework for making explicit the interdependence of epistemological, ontological, and ethical concerns relevant to the conditions that make possible objective description. More recently, Boon's (2015a, 172) 'epistemological constructivism' position is similarly proposed as a way of side-stepping the realism/relativism debates.

refer

Interest in concepts often focus on concept *reference* – i.e., on the roles of concepts as representational tokens: a scientific concept is used to refer to the class of object/entity that concept represents. While understanding the processes of reference within the sciences is important, it is outside the present scope.

As explained in Chapter Two, I am interested in the *uses* of **scientific concepts** rather than questions about whether these concepts refer to a discrete type of enduring phenomena. This focus builds on scholarship that demonstrates how concepts can play useful roles in scientific conceptual hierarchies even if they fail to pick out eternal scientific kinds (Bloch 2012b; J. McCaffrey and Machery 2012, 270). One such use for concepts is to **individuate** instances of a class of phenomena of interest for the purpose of investigation (U. Feest 2010, 173). In this way, regardless of whether a given concept for SLMP refers to a discrete type of **SLMP**, it is by individuating instances of a specific conceptualisation of SLMP that it is possible to investigate the neurophysiological **mechanisms** that underlie the type of phenomena conceptualised (mental imagery or hallucinations).

representationalism

Representationalism is sometimes used for the focus on questions about the correspondence between scientific descriptions and reality. There has been a shift away from this interest in correspondence within the fields of research investigating **scientific practices** that I draw upon. For example, within STS the focus shifted away to the representations themselves, and towards the dynamic and heterogeneous *performances* that contribute to a given representation (e.g., Barad 2007; Pickering 1995b). Meanwhile, historical and philosophical studies of scientific practices have shifted away from questions of meaning and reference to focus on the contingent development and *uses* of scientific concepts (e.g., Brigandt 2012; Kindi 2012; U. Feest 2010).

resistance

I am following Pickering's use of the term resistance (as detailed in Chapters One and Two). Although Pickering is not explicit, I am taking the notion as a metaphor for resistance as it is understood in engineering – as a measure of how a material substance can reduce the flow of an electric current in one direction.[207] Similarly, resistance from the materiality of instruments can reduce the ease with which humans can attain the outcome they intended when using the instrument in question. This use is consistent with similar uses by other scholars. For an example, Fleck (1979, 38–41) argued that the knowing subject must engage with the resistances from both the object to be known and the existing fund of knowledge within the community in question. Similarly, Rouse (1996, 134–35) included a similar – yet independently developed – notion of resistance in his ten theses about scientific practices: "(1) practices are composed of temporally extended events or processes; (2) practices are identifiable as patterns of ongoing engagement with the world, but these patterns exist only through their repetition or continuation; (3) these patterns are sustained only though the establishment and enforcement of 'norms'; (4) practices are therefore sustained only against resistance and difference and always engage relations of power; (5) the constitute role of resistance and difference is a further reason why the identity of a practice is never entirely fixed by its history and thus why its constitutive pattern cannot be conclusively fixed by a rule (practices are open to continual reinterpretation and semantic drift); (6) practice matters…; (7) agency and agents (not necessarily limited to individual human beings) who participate in practices are both partially constituted by how that participation actually develops, and in this sense, 'practice' is a more basic category than 'subject' or 'agent'; (8) practices are not just patterns of action, but the meaningful configurations of the world within which actions can take place intelligibly, and thus practices incorporate the objects that they are enacted with and on and the settings in which they are enacted; (9) practices are always simultaneously material and discursive; (10) practices are spatiotemporally open, that is, they do not demarcate and cannot be confined with spatially or temporally bounded regions of the world."

It is nonetheless worth noting that the term 'resistance' has been used in other ways; and other approaches that intersect with Pickering's use of resistance have been explored with different terminology.[208] For an example of the former, see Rheinberger for a view that emphasises how notions of resistance are not *just* articulating the obstacles materiality presents to human goals, but also highlight how unexpected aspects of materiality can divert

[207] Thank you to maia sauren for suggesting this clarification.

[208] I own my appreciation of the importance of these nuanced understandings of 'resistance', to Kristian Camilleri.

the attention of a researcher away from their initial goal (even momentarily and potentially unfruitfully) without necessarily obstructing the pursuit of the initial goal *per se*.[209] For an example of the later, it is worth considering the similarities and differences in the notions of 'resistance' and 'constraints' (Pickering 1995b, 65–67, 1995a, 43, note 1; Galison 1995, 27, note 7; Vertesi 2015, note 3 in Chapter 7).

Finally, as Frederic Holmes (2004, 7) notes, while this notion of resistance contributes to an innovative philosophical shift – towards recognising that "Scientists cannot fully control or foresee the outcomes of their conceptual and experimental practice, and time alters both their intentions and their performances" – it is often taken as a mundane reflection by historians of science. This supports my argument, developed in Chapter Two, that Pickering's approach offers avenues for drawing together insights from varied approaches within the broader field of historical, philosophical, and social studies of scientific practices.

resistance-accommodation dialectic

See 'mangle of practice'

ROI (regions of interest)

Regions of interest (ROI) are neuroanatomical regions of the brain that have been defined for the purposes of an fMRI experiment. I discuss these in more detail in Chapter Five.

scientific concepts

When talking about concepts, I am specifically interested in the uses of ***scientific concepts***. I will not be discussing the literature around the development or use of general concepts (which is extensive and crosses over several disciplines: including the cognitive sciences, the philosophy of language; philosophy of mind, and education theory).

Following others, I am treating *scientific concepts* as **bodies of knowledge** that **individuate** a type of phenomena from various other phenomena such that they can be further investigated. These concepts are distinct from theory. In contrast to a theory, concept cannot be either true or false; it is merely appropriate or inappropriate in relation to specific goals. See (Steinle 2010b; U. Feest 2010; Bloch 2012a, 2012b). I therefore adopt a specific view of scientific concepts: one where concepts are bodies of knowledge that are considered to play

[209] Based on an overall impression from Rheinberger's (2009, 2011) discussion of the notion of 'resistance' in the work of others, such as Fleck and Bachelard, as well as within his own account of experimental systems.

useful roles in conceptual hierarchies even when they fail to pick out an eternal natural scientific kind (Bloch 2012b; Brigandt 2003; Pöyhönen 2013; C. K. Waters 2014).[210]

Furthermore, concepts can be used as theoretically polyvalent in experiments that are autonomous and distinct from theory. For example, Steinle (2010b, 2016) details how concepts can be formed within exploratory experiments that are similarly independent of theories. Another example is the demonstration provided by Arabatzis (2012, 162) of how concepts can contribute to experimental research in ways that are not determined by the theoretical frameworks within which the concept might also be embedded.

Although not discussed in my text, it is worth noting that some concepts can be used as exhaustive and mutually exclusive (object concepts) while others are neither exhaustive nor mutually exclusive and instead represent a sequence of events over time (process concepts). (Barker 2011, 462).

Also, although the psychological uses of concepts are beyond the present scope, it is also worth noting that McCaffrey and Machery (2012, 270) discuss the possibility of replacing 'concept' within the theoretical vocabulary of the cognitive sciences with terms that better "refer to the bodies of knowledge actually used in the processes underlying out cognitive competences". It would be interesting to position this suggestion in relation to the recent accounts of concept-use within philosophy of science. Specifically, those approaches that describe **scientific concepts** as used as dynamic bodies of knowledge (rather than as merely mental or linguistic representations of a static object/phenomena).

scientific knowledge

As discussed in detail in Chapter One, I am working with a view of scientific knowledge as a collective resource that provides objective accounts of the real world (in the sense of robust and intersubjective explanations of objects/phenomena that exist independently of human access) that are contingent on the conditions (including material, social, and conceptual resources) that contribute to the situations within which this knowledge was generated. For example, I use the phrase **contingent yet objective scientific knowledges** to highlight approaches within both **STS** and **HPS** that seek to bypass **realist** and **constructivist** traps by describing **scientific knowledge** as able to provide objective accounts (i.e. as robust,

[210] Empirical research in cognitive psychology supports this approach by suggesting that the family-resemblance accounts of concept formation involves a process of framing structural connections rather than picking out ultimate natural kinds (Andersen, Barker, and Chen 2006, 45).

intersubjective knowledge of something not dependent on human access) of the real world in ways that are nonetheless contingent on the situated practices though which this account was produced.

scientific practice

I use this phrase to emphasise an interest accounts that describe how scientific **knowledge claims** are *generated* within the sciences as practiced (both historically and currently), rather than in accounts that seek to describe (or dictate) how rarefied scientific knowledge is (or should) be justified and disseminated. Contributing to the broader collection of historical, philosophical, and social studies of the sciences *as practiced*, are the overlapping fields of **STS** and **HPS**. For more detail, see Chapter One.

sedimentation

As detailed in Chapter Eight, I am building on Friedrich Steinle's (2010a, 200) adaptation of Husserl's notion of sedimentation and adapts it to explore how experimental **scientific concepts** that emerged in a specific context latter came to appear as solidified and stable 'natural' categories (if not as facts). Also see: **black boxes**

sensitive insanity

A term defined by T. Arnold (1782, 158) as describing "erroneous images which are excited in the mind, relative to the person's own form". Compare: **mental imagery** and **hallucinations.**

service-user movements

Service-user approaches are those that focus on improving patient experiences rather than explaining pathology. For some discussion of these approaches as they relate to research practices, see the special issue of *Philosophy, Psychiatry, & Psychology* edited by Jayasree Kalathil and Nev Jones (2016).

A topical example is the 'hearing voices movement': a service-used led network that advocates for people who 'hear voices'. This network incorporates local groups, as well as state and national *Hearing Voices Networks,* and an international organisation *Intervoice* (B. Gray 2008). Voice-hearing experiences are commonly regarded as evidence of **AVH**s and symptomatic of psychiatric diagnoses such as schizophrenia (Bruijnzeel and Tandon 2011). As such, many people who hear voices have used psychiatric services. When it comes to psychiatric-user movement there are a range of diverse positions that converge on common criticisms of psychiatric practice (Cohen 1998, 155). Some campaigns focus on normalizing mental illnesses by legitimising their status as biomedical diseases; others vocally oppose the limitations of the biomedical model and advocate for a broader understanding that incorporates all aspects of distress (Woods 2011, 128). The hearing-voices movement takes the latter stance to argue that the biomedical model is limited and that psychiatric treatments are not the only way of managing distressing voice-hearing. However, this does not mean that psychological distress is regarded as merely socially determined. Sceptical acceptance of biological differences found between people who do not hear voices and those experiencing distressing voice-hearing allows recognition of these findings while simultaneously criticising the causal connection. For example, the coordinator of the *Intervoice Scientific Committee*, Eleanor Longden (2012), a practicing psychologist and chronic voice-hearer, argues that biological differences associated with distressing voice-hearing may be linked to life-adversities such as trauma rather than a psychiatric diagnosis (Also see: Longden, Madill, and Waterman 2012, 41–43). It is this characterisations of voice-hearing that underlies the movement's aims to support members in managing distressing **voice-hearing experiences** with holistic methods that can include voluntary use of psychiatric services (Watkins 2008). For example, while coercive medicating practices are heavily criticised, voluntary and participatory decisions to take (or not take) medications are considered a tool that can be used within broader management strategies (Longden, Madill, and Waterman 2012, 41–43).

situated knowledges

This refers to Haraway's (1991, 1994, 2006) argument that objective knowledge of the real world can be produced by locating it at the intersection of multiple partial and situated perspectives. Haraway's notion of **objectivity** through partial perspectives calls to mind Bachelard's statement that "there can be no objectivity without a proliferation of viewpoints" (quoted in Rheinberger 2010a, 35 (Also see: Bachelard 1953 Le matérialisme rationnel. p.215 (note 57 in ch.2))). In addition, Haraway's notion of 'situated knowledges' has been developed in diverse directions; see (Bhavnani 1993; Feinberg 2008; Ihde 2012; Law 2009; Sassower 1994). An example that is especially relevant to this thesis is Ron Eglash's (2011) proposal that an 'anti-relativist' view of situated knowledges as providing a view of 'multiple objectivity'.

SLMP

Pronounced 'SliMPh', SLMP stands for *sensory-like mental phenomena* – an analytic category for a range of mental phenomena experienced, to varying degrees, 'as if' the relevant sensory system has been stimulated despite the absence of relevant perceptual stimuli. Within this range of phenomena, I am interested in those investigated by using one of two specific **scientific concepts** for SLMP: **mental imagery** and **hallucinations**.

To understand this categorisation, it helps to appreciate that, while differing in their details, the concepts of mental imagery and hallucinations both share a core feature. This feature is evident in the inclusion in their respective definitions of a description of conscious experiences of sensations that occur in the absence of relevant sensory stimuli (e.g., André Aleman and Larøi 2008, 15; Roeckelein 2004, 11). It is also evident in reported experiences of both mental imagery and hallucinations with **phenomenal properties** that are described as 'heard', 'seen', 'tasted', 'felt' and so forth (Casey 2000, 41–45; Landis and Mettler 1964, 113).

Note that I am specifically interested in the conscious **endogenous** experiences of SLMP conceptualised as either mental imagery or hallucinations, not experiences of SLMP *per se*. Therefore, while I will mention other concepts for specific experiences of SLMP as they relate to either mental imagery or hallucinations, categorising all the various concepts used for experiences of SLMP is unnecessary. Some brief examples will suffice: conscious endogenous experiences of SLMP might include the 'crossed-wire' experiences of synaesthesia and phantom pain, non-endogenous conscious experiences include induced altered states; and dreams are the obvious example of SLMP experienced while unconscious. Here I am following Catherine Craver-Lemley and Adam Reeves (2013), and not considering the experiences of synaesthesia within the concept of mental imagery.

It is also worth noting that the notion of SLMP is an over-arching analytic category within which the *uses* of the concepts of mental imagery and hallucinations in neuroimaging experiments that provides a way to discussed both without being side-tracked by questions of concept-reference. To put that another way, this analytic approach provides a way to maintain a degree of ambivalence about whether the types of mental phenomena that these two concepts each refer to are related to each other (beyond being experienced as SLMP) or whether they are **Neuroscientifically relevant psychological** (NRP) factors.

SLMP-neuroanatomical-correlates

These are the reported correlations between experiences of **SLMP** (conceptualised as either **mental imagery** or **hallucinations**) and **neurophysiological processes**. The neurophysiological processes found to correlates with SLMP are the localised changes in

neural activity (as measured by BOLD **fMRI**) that correlate with a specific experimental condition intended to isolate the type of SLMP conceptualised.

As such, SLMP-neuroanatomical-correlates are taken to be the entities (anatomical regions of the brain) and their activities (changes in neuronal activity within these regions during an experimental condition) that are indirectly measured with neuroimaging techniques in a way that correlates to experiences of SLMP (as isolated by the experimental conditions).

Based on these SLMP-neuroanatomical-correlates, neurophysiological processes are proposed to explain the underlying mechanism of experiences of mental imagery or hallucinations.

In line with their entrenched sets of inverse associations, these SLMP-neuroanatomical-correlates are proposed to indicate specific neurophysiological processes of a **mechanism** explaining the functional role of mental imagery in neurocognition or the dysfunctional neurocognition of hallucinations. As such, the SLMP-neuroanatomical-correlates being investigated in neuroimaging experiments can be considered a key aspect of the mechanisms sought to explain either mental imagery or hallucinations.

SLMP state

Within the present context, state of **SLMP** indicates an acute experience of SLMP. Typically, this is investigated by comparing results acquired during a period of such an experience with those results acquired during a period without SLMP experiences. See Chapter Five for more detail.

SLMP trait

Within the present context trait for SLMP indicates a predisposition towards experiencing SLMP. Typically, this is investigated by comparing the results for a group expected to experience a given type of SLMP compared to results to a group not expected to experience the SLMP in question. See Chapter Five for more detail.

social-constructionism

Social-constructionism is used to describe the view that **scientific knowledge** is entirely-relative to the context that produced it and, in some cases, that there is no mind-independent reality open to scientific study (Baghramian and Carter 2015). Closely associated with this view are the relativist views about **scientific knowledge** that emerged within Sociology of Scientific Knowledge (SSK) during the 1970s and 1980s (for some examples, see work by

David Bloor and Harry Collins). Given this, high-profile *social* explanations proposed for the way that contingencies can contribute to **scientific knowledge** have been criticised for supporting social-constructionist views. However, as outlined under entries for **constructivist** and **realist** accounts of the *material* contributions to scientific practices the relativism associated with constructionism has been firmly rejected by the scholars within STS and HPS that I have drawn upon.

STG (superior temporal gyrus)

The STG a **neuroanatomical region** of the brain and often investigated as a region of interest (**ROI**) in **fMRI** experiments. It consists of the superior convolution (gyrus) of the temporal lobe of the brain. The STG is one of the six major convolutions located in the temporal lobe of the brain this region also contains the most overlapping sub-divisions of those considered (see supplementary material). Firstly, the upper margin of the STG, called the *temporal operculum*, curls over the ventral portion of the insula and is divided into three parts: *the planum polare,* the *transverse temporal gyri* (Heschl's gyri)*,* and the *planum temporale* (Clarkson, Rosse, and Mejino 2015; Duvernoy 1991, 7). The size of these anatomical landmarks vary between individuals, with the planum temporale especially variable and sometimes entirely absent (Duvernoy 1991, 10). Furthermore, within each individual, the size and configuration of the STG region differ between each hemisphere – typically being more extensive in the left hemisphere (Nolte and Angevine 2013, 240). Of these three parts, the *transverse temporal gyri* is further divided into two short oblique convolutions called the *anterior transverse temporal gyrus* (BA41) and the *posterior transverse temporal gyrus (*BA42) (Federative Committee on Anatomical Terminology (FIPAT) and International Federation of Associations of Anatomists 2011, 125). In addition, various Brodmann's areas (BAs) and a range of other functional regions are commonly located within the STG. These include the primary auditory cortex (roughly aligning with BA41), the secondary auditory cortex (roughly aligning with BA42, and part of BA22), and part of the language comprehension region known as *Wernicke's area* (within the posterior part of BA22) (Anthoney 1994, 587; Bowden 2015; Duvernoy 1991, 7, 10).[211] Likewise, the anterior end of the STG extends into the temporal pole (BA38) and is associated with a wide variety of functions including memory, executive functions, and emotional regulation (Bernal and Perdomo 2008). Finally, in

[211] As mentioned earlier, Wernicke's area is an example of the variable use of functional terms for neuroanatomical regions and the anatomical boundaries vary widely.

addition to those already mentioned, the STG is also considered to include BA13, BA21, and BA39 (Bowden 2015; Clarkson, Rosse, and Mejino 2015).

STS

In this context, STS is for Science and Technology Studies - an amalgamation of overlapping research approaches that, although having contested boundaries, coalesces around the broad range of questions related to the role of science and technology within society. As a discipline STS is often characterised by wide-ranging debates (M Callon 1995; Jasanoff, Markle, and Peterson 1995; Sismondo 2010). One of these, has been the turbulent relationship between philosophical and sociological approaches to studying the interactions between science and society within STS; see (Giere 1987; Roosth and Silbey 2009). Within STS there are various anti-essentialist approaches that position the sources and interpretations of knowledge and artefacts as complex, multiple, and produced through interactions between the material and social worlds (Sismondo 2010, 11). However, while insisting on a view of **scientific knowledge** as constructed – rather than discovered – many STS approaches also explicitly diverge from relativism of construction type accounts (Casper Brunn Jensen 2003b, 237). When emphasising contingency in relation to the heterogeneous participants in the sciences, scholars contributing to STS have actively distanced themselves from the alternative over-emphasis on the *social* construction of scientific knowledge by describing their views as a form of **constructivism.** As discussed in Chapter One, there is significant overlap between STS and **HPS** approaches to studying **scientific practices**.

synchronic

A term for, or pertaining to, things occurring at the same point in time (rather than over time). For example, synchronic accounts of science are typically ahistorical, assuming no meaningful temporal relations (Cat 2017). Compare: **diachronic.**

tacit knowledge

Tacit knowledge are experiences of intuitive or procedural knowledge that are not able to be communicated explicitly. The use of the term has been discussed within both psychology and philosophy of knowledge; see (Collins, Barnes, and Edge 1982; Polanyi 1966; Pylyshyn 1992). Within HPS, the term is attributed to Michael Polanyi – from whom Kuhn and others explicitly adopted it. For example, Chang (2014, 71) draws on Polanyi to remind that "many of the important skills for scientific work are located in the body, and therefore not reducible to belief or knowledge in the form of propositions". In this context, the notion of tacit knowledge is associated with that of *embodied* knowledge.

technical relativism

The notion that **scientific knowledge** is dependent entirely of technical culture. In addition to distancing his work from the *social* **relativism** associated with **social-constructionism** Pickering (1995b, 202) emphases that his approach is also *not* a form of technical relativism.

technoscience

A neologism common to a strand within **STS** that highlights the dynamic and intermeshed sets of **sociotechnical** relations that form the scientific practices within which so much knowledge is generated (Eason 2003, 172).

theories

Following others, I am treating scientific theories as distinct from **scientific concepts**. As with Steinle (2010b, 36), I am taking theories to be explicit attempts to provide a system of explanation for a given type of phenomena; attempts that might provide an accurate (true) or inaccurate (false) explanation. In contrast, concepts are not explanations in and of themselves but, as fundamental elements of thought, are necessarily used in explanations. As such, a concept cannot be either true or false; it is merely appropriate or inappropriate in relation to a specific goal. Also note that regularities – formulated as 'if-then' laws that specify the set of conditions under which a particular type of phenomena occur (Steinle 2016, 316–20) – can be treated as distinct from both theories and concepts. Also see: **experimental investigations**.

vividness

Vividness is a common **phenomenological characteristic** to measure when studying **mental imagery**; especially in the visual **modality**. In this context, vividness "is traditionally defined as a construct expressing the self-rated degree of richness, amount of detail (resolution), and clarity of a mental imagery, as compared to the experience of actual seeing" (D'Angiulli et al. 2013, 1). The vividness of perceptual-likeness is also evident in other sensory modalities. For example, Steven Brown (2006, 29) described 'hearing' a tune in his head that showed a "high acoustic fidelity with regard to pitch, loudness, rhythm, tempo, and timber" such that he was able to "differentiate various instruments, and…attain orchestral richness".

voluntary hallucinations

Another term for **eidetic imagery**

Appendix 2 (Supplementary Tables)

Set 1: Search Records

Please note, these tables are provided as a record of the tools/processes involved in analysis. They are not intended for communicating the results of these analyses (which are detailed in Chapter Five).

Table 10: Search key-word combinations (supplementary table)

<table>
<tr><td colspan="4">KEYWORDS</td></tr>
<tr><td rowspan="3">Either:</td><td>MENTAL IMAGERY
"mental imagery" OR "mental image"
(including related terms)</td><td rowspan="2">OR</td><td>HALLUCINATIONS
hallucinations, OR hallucinate, OR hallucinating
(including related terms)</td></tr>
<tr><td>AND</td><td>AND</td></tr>
<tr><td colspan="3">NEUROIMAGING TECHNIQUES:
"functional neuroimaging" OR "brain map" OR "functional ROI" OR "region of interest OR "functional connectivity MRI"
OR "functional magnetic resonance imaging" OR "regional cerebral blood flow" OR "magneto-encephalography"
OR "positron emission tomography" OR electroencephalography</td></tr>
</table>

Table 11: Search records for individual databases (supplementary table)

Initial Search Streams:		MENTAL IMAGERY	Neuroimaging Techniques	HALLUCINATIONS	
Database 1: OVID MEDLINE					Totals
	Limit to:	(Journal Articles and human subjects)			
Level 1	Totals	6118	8744	7516	22378
Level 2	Combined (AND)	95		51	146
Search Level 2: Limit A	Limit: published 2004-2014	69		39	108
Database 2: OVID PsycINFO					Totals
	Limit to:	("0110 peer-reviewed journal" and human subjects)			
Level 1	Totals	7096	8593	4049	19738
Level 2	Combined (AND)	93		56	149
Search Level 2: Limit A	Limit: published 2004-2014	72		46	118
Database 3: OVID ALL JOURNALS					Totals
	Limit to:	(Journal Articles and human subjects)			
Level 1	Totals	10580	10003	7265	27848
Level 2	Combined (AND)	502		92	594
Search Level 2: Limit A	Limit: published 2004-2014	448		69	517
COMBINED OVID DATABASES					Total
Level 2:		690		199	889
Limit: published 2004-2014		589		154	743

Table 12: Article selection process (supplementary table)

Combined OVID Search Stream:		Neuroimaging + MENTAL IMAGERY (Set-M)	Neuroimaging + HALLUCINATIONS (Set-H)	Totals
Starting totals	Limit: published 2004-2014	589	154	743
SCREENING	Remove Duplicates	516	110	626
CULL 1 -3	Exclusion Criteria	Exclude: meta-analyses; reviews; non-English languages; not matching search criteria		
	Excluded	-368	-46	-414
	Remaining:	148	64	212
	Limit to:	Keywords in: Title; Keyword List; or Abstract		
	Excluded	-23	-6	-29
	Remaining:	125	58	183
	Limit:	Exclude: use of concept for investigating unrelated topics		
	Excluded	-44	-10	-54
	Remaining:	81	48	129
CULL 4	Limit to:	Techniques include fMRI		
	Excluded:	-2	-3	-5
	Remaining:	79	45	124
CULL5	Limit to:	Studies investigating sensory modalities included in both sets (visual and/or auditory)		
	Excluded:	-31	-0	-31
	Remaining:	48	45	93
CULLs 6-8	Limit to:	Studies where the MI or Hs is being investigated directly and for its own sake		
	Excluded:	-25	-16	-41
	Remaining:	23	29	52
CULL 9	Limit to:	Articles in an A ranked journal and/or with a citation/yr. >1		
	Excluded:	-0	-2	-2
	Remaining:	23	27	50

Set 2: ROI Analysis

Please note, these tables are provided as a record of the tools/processes involved in analysis. They are not intended for communicating the results of these analyses (which are detailed in Chapter Six). Please also note that, given their purpose and my own accessibility requirements, these have not been prepared to meet standard accessibility metrics. Alternative formatting can be supplied upon request.

All the ROI analysis supplementary tables share the same three formatting keys:

1) All articles listed by year of publication (and then alphabetically by first author):
    a) Set-M = green/lighter background
    b) Set-H = purple/darker background
2) Key for SLMP Modality Initialisms:
    a) Hs = hallucinations:
    b) VH = visual Hs;
    c) AH = auditory Hs;
    d) AH(v) = auditory verbal Hs;
    e) MI = mental imagery:
    f) VMI = visual MI;
    g) AMI = auditory MI;
    h) AMI(v) = auditory-verbal MI; MMI = multimodal MI
3) Key for FORMATTING used to indicate type of SLMP-neuroanatomical-correlates:
    a) Yellow Fill = increased activity;
    b) Orange Fill = decreased activity;
    c) Red text = change in activity 'during' SLMP;
    d) Black text = change in activity as a 'group' trait comparison;
    e) Bold = change in activity 'greater' than [x];
    f) Italics = change in activity 'less' than [x];
    g) Blue Fill = change in activity related to another ROI (connectivity);
    h) Pattern = no difference in change in activity;
    i) Grey text = additional non-SLMP findings.

Table 13: Summary of analysis for STG as a region of interest (supplementary table).

	SUPERIOR TEMPORAL GYRUS (STG)						
			Temporal operculum				
				Transverse Temporal Gyri (Heschl's Gyri)			
Neuro-anatomical Terms	Poler part of STG	**Anterior STG**	**Planum Polare**	**Anterior transverse temporal gyrus**	**Posterior transverse temporal gyrus**	**Planum Temporal**	**Posterior STG**
Broadman's Areas	BA38	BA22		~BA41	~BA42	BA22	
Functional Terms				~ Auditory cortex (in dominant hemisphere)		~ Auditory association cortex/ majority of Wernicke's area (in dominant hemisphere)	
Ganis et al (2004)	Increase in STG during VMI (relative to baseline)						
Halpern et al (2004)	Increase in STG during AMI (relative to baseline)						
	Bilateral STG decrease during VMI (relative to baseline)						
	Increase in the STG during AMI task greater than during VMI (bilaterally, with a greater increase in the right hemisphere)						
	Increase in STG during AMI task less than for perception task						
Just et al (2004)	Increase in STG during an imagery task (involving VMI and possibly AMI) relative to baseline						
	Increase in STG during an imagery task (involving VMI and possibly AMI) less than a non-imagery task.						
Sato et al (2004)	Left Increase during AMI(v) (relative to baseline)						
Van de Ven et al (2005)				Bilateral increase in STG during AH(v) (relative to baseline)			
Bunzeck et al (2005)						Bilateral STG increase during AMI (relative to baseline)	
				No difference in the STG during AMI (relative to baseline)			
Rudner et al (2005)	Increase in left STG during AMI(v) recognition & AMI(v) manipulation (relative to baseline)						
	Increase in right STG during AMI(v) manipulation (relative to baseline)					Bilateral STG increase during AMI(v) manipulation (relative to baseline)	
Butler et al (2006)	STG connectivity with another ROI (insula) during VMI different						

	SUPERIOR TEMPORAL GYRUS (STG)					
	between two healthy subject groups (less in men than women)					
Hoffman et al (2007)			Increase in left STG during AH(v) (relative to baseline)		Increase in left STG during AH(v) (relative to baseline)	
Mechelli et al (2007)	No difference in connectivity between left STG and right IFG between AH(v) group and non-AH(v) groups for a task of assessing the identity of the voice in the auditory stimuli					
	STG connectivity with other ROI (CG) for AH(v)-group less when identifying a recording of another person's voice than when identifying a recording of their own voice. The opposite trend was measured in both the non-Hs group and healthy control group					
Ramírez-Ruiz et al (2008)		Decrease in right STG (relative to baseline) in group of PD patients with VHs			Decrease in right STG (relative to baseline) in group of PD patients with VHs	
Zhang et al (2008a)		**Increase in left STG for AH(v) group greater while identifying familiar voices than while identifying unfamiliar voices**			**Increase in left STG for AH(v) group greater while identifying familiar voices than while identifying unfamiliar voices**	
		Increase in right STG less in AH(v) group than in non-Hs group			*Increase in right STG less in AH(v) group than in non-Hs group*	
Zhang et al (2008b)					Bilateral increase in STG in AH(v) patient group while undertaking a perception task (relative to baseline)	
					No difference in STG activity (relative to baseline) between AH(v) group and healthy control group	
					Increase in STG (relative to baseline) greater in AH(v) patient group than in non-Hs patient group	
Ford et al (2009)		Bilateral increase in STG in AH patient group while undertaking an auditory task				
		Increase in left STG greater than that in the right STG for AH patients doing an auditory task				
		Increase in STG less in BA22 than BA42 for AH patients doing an auditory task		**Increase in STG greater in BA42 than**	*Increase in STG less in BA22 than BA42 for AH patients doing an auditory task*	

	SUPERIOR TEMPORAL GYRUS (STG)				
				BA22 for AH patients doing an auditory task	
		Increase in STG for AH patient group undertaking an auditory task less than that for healthy control group			
			Increase in left STG while doing an auditory task less for AH group than for non-AH group		
Raij et al (2009)			Increase in left STG during AH(v) (relative to baseline)		
				Increase in right STG during AH(v) (relative to baseline)	
			Bilateral STG connectivity with another ROI (IFG) was greater when subject's severity (SRH) scores were highest.		
Wible et al (2009)	Increase in left STG during memory task (relative to baseline) in Hs patients				
	For Hs patients doing a memory task, the increase in STG (relative to baseline) was greater the higher the AH(v) severity score of the patients				
	Increase in left STG while doing a memory task (relative to baseline) less in Hs group than in non-Hs patient group				
Bird et al (2010)	Increase in right STG during VMI (relative to baseline)				
Diederen et al (2010)			Decrease in left STG prior to AH(v) (relative to baseline)		
			Bilateral increase in STG during AH(v) (relative to baseline)		
Escartí et al (2010)	No difference in STG between AH patient group, non-AH patient groups, and healthy control group				
Gavrilescu et al (2010)			*STG connectivity with other ROI less for AH patient group than for both non-AH patient group and healthy control group*		
			STG connectivity between left and right hemispheres less for AH patient group than for both non-AH patient group and healthy control group		
Korsnes et al (2010)	Bilateral increase in STG (while doing a listening task) observed in both epilepsy patients with AHs and control group				

	SUPERIOR TEMPORAL GYRUS (STG)		
	Bilateral increase in STG (while doing listening task) less in epilepsy patients with AHs than in control group		
	Left lateralisation was greater for epilepsy patients with AHs than for the control group		
	STG increase less for the AHs group than for the control group		
	*Less of an increase in STG correlated with higher scores in the severity*frequency*duration of Ahs*		
Weiler et al (2010)			Bilateral STG increase during VMI in anticipation & during VMI in memory (relative to baseline)
Hoffman et al (2011)			*Connectivity between the left STG and left IFG less in the patient groups (both AH(v) and non-AH(v)) than in control group*
			No difference in connectivity between the left STG and left IFG for AH(v) group and control group
			Connectivity between the left STG and left IFG greater for AH(v) patient group than for non-AH(v) patient group
			Corticostriatal connectivity (between the left STG and left IFG, and the putamen) was greater in AH(v) group than in non-AH(v) patient group and non-patient controls
de Borst et al (2012)	Bilateral increase in STG during construction of VMI, but not during inspection of VMI (relative to baseline)		
Doucet et al (2012)	**STG connectivity with other ROI greater the longer the experience of VMI**		
	STG connectivity with other ROI less when the experience of VMI is longer than that of language-based thoughts (including, but not limited to, AMI(v))		
Sommer et al (2012)		*Left STG connectivity with another ROI (left hippocampus) less in the patient groups than in control group*	
		Left STG connectivity with another ROI (left hippocampus) less in patients with higher Hs severity scores	
		Left STG connectivity with another ROI (left hippocampus) decreased during AH(v) periods compared to during non-Hs periods	
		Left STG connectivity with other ROI (IFG and IPL) less in AH(v) group than control group	

	SUPERIOR TEMPORAL GYRUS (STG)						
			No difference in left STG connectivity with other ROI when comparing patients during Hs periods and non-Hs periods				
Ćurčić-Blake et al (2012)						No difference in bilateral increase in STG for 'inner speech' task between AH(v) group, non-AH(v) group, and control group	
						STG connectivity (from left Wernicke's area) to another ROI (left IFG) less in AH(v)-group than in control group	
Diederen et al (2013)		**Interhemispheric STG connectivity greater in (non-patient) AH(v) group than in control group**				**Interhemispheric STG connectivity greater in (non-patient) AH(v) group than in control group**	
		Connectivity between left STG and right IFG less in the (non-patient) AH(v) group than in the control group				*Connectivity between left STG and right IFG less in the (non-patient) AH(v) group than in the control group*	
Koeda et al (2013)	**No difference for STG between control group and patients with AH(v)-prone schizophrenia (both had increase in STG bilaterally that was greater for favourability judgement task (FJT) than for gender-differentiation task (GDT))**						
	Increase in left STG for GDT task less in patients with AH(v)-prone schizophrenia than in control group						
	Increase in left STG correlated with higher score in patient PNASS scores (for AH(v)-prone schizophrenia)						
Zvyagintsev et al (2013)						Bilateral STG increase during AMI(v) (relative to baseline)	
				Bilateral STG decrease during VMI (relative to baseline)			
		Increase in right STG during AMI(v) greater than during VMI			Bilateral STG decrease during AMI(v) (relative to baseline)	**Increase in right STG during AMI(v) greater than during VMI**	
		Increase in left STG during AMI(v) greater than during VMI					

	SUPERIOR TEMPORAL GYRUS (STG)				
		Increase in STG during AMI(v) (relative to baseline) greater with higher ‘vividness’ scores			**Increase in STG during AMI(v) (relative to baseline) greater with higher ‘vividness’ scores**
Amad et al (2014)	*Bilateral STG connectivity with another ROI (hippocampus) less in AHs group that in AHs&VHs group.*				
Goetz et al (2014)		Decrease in right STG during VHs (relative to baseline)			Decrease in right STG during VHs (relative to baseline)
van Lutterveld et al (2014)	Increase in STG during AH(v) (relative to baseline)				
	STG connectivity with other ROI greater for AH(v) group than for non-Hs group (including both ‘connectivity strength’ and ‘between centrality’).				

Table 14: Summary of analysis for IFG as a region of interest (supplementary table)

	INFERIOR FRONTAL GYRUS (IFG)		
Neuro-anatomical Terms	**Pars orbitalis**	Frontal operculum	
		Pars triangularis	**Pars opercularis**
Brodmann Areas	BA46 and BA47	BA45	BA44
Additional Structural Terms	Anterior to pars triangularis, forms the lower boundary of the gyrus and overlies the insula.	Posterior to pars orbitalis and anterior to the pars orbitalis	Posterior to pars triangularis
Functional Terms		Broca's Area	
Ganis et al (2004)	Bilateral increase in IFG during VMI (relative to baseline)		
	No difference between IFG during experiences of VMI and perception.		
Halpern et al (2004)	Increase in IFG during VMI (relative to baseline)		
	Increase in IFG during AMI(v) (relative to baseline)		
	No difference for IFG during experiences of VMI compared to during experiences of AMI(v)		
	No difference for IFG between during experiences of VMI and perception		
Just et al (2004)		No difference in IFG (pars triangularis) during imagery task (involving VMI and possibly AMI) compared to non-imagery task.	**Increase in IFG (pars opercularis) greater during an imagery task (involving VMI and possibly AMI) than a non-imagery task.**
Sato et al (2004)		**Increase in left IFG greater during AMI task than for non-imagery task**	
	Increase in right IFG greater during AMI task than for non-imagery task (not as much as on the left)		
Stebbins et al (2004)			**Increase in IFG for VHs group greater than that in non-Hs group**
Rudner et al (2005)	Increase in left IFG during AMI(v) (relative to baseline)		
			Increase in right IFG during the manipulation of AMI(v) greater than that during the generation of AMI(v)
Butler (2006)	Increase in IFG during VMI (relative to baseline)		
	No difference for IFG during VMI between (male and female) groups		
Kana et al (2006)	Increase in IFG during VMI task (relative to baseline) in healthy subjects		
	Increase in IFG during VMI task (relative to baseline) in subjects with autism (patients)		
	Increase in LEFT IFG during VMI (relative to baseline) greater in healthy group than in patient group (with ASD).		**Increase in RIGHT IFG during VMI (relative to baseline) greater in healthy group than in patient group (with ASD).**
Hoffman et al (2007)	Bilateral increase in IFG during AH(v) (relative to baseline)		

<table>
<tr><th></th><th colspan="3">INFERIOR FRONTAL GYRUS (IFG)</th></tr>
<tr><td>Mechelli et al (2007)</td><td colspan="3">No difference in connectivity between right IFG and left STG between AH(v) group and non-AH(v) groups while assessing the identity of the voice in the auditory stimuli.</td></tr>
<tr><td>Ramírez-Ruiz et al (2008)</td><td>*Increase in IFG less in VHs group than non-Hs group*</td><td colspan="2"></td></tr>
<tr><td rowspan="2">Raij et al (2009)</td><td colspan="3">Bilateral increase in IFG during AH(v) (relative to baseline)</td></tr>
<tr><td colspan="3">**Bilateral IFG connectivity with other ROI were greater when subject's severity (SRH) scores for AH(v) were highest**</td></tr>
<tr><td rowspan="3">Wible et al (2009)</td><td colspan="3">Increase in IFG for AHs group while doing a memory task (relative to baseline)</td></tr>
<tr><td colspan="3">No difference in IFG for memory task (relative to baseline) between any groups (including AHs-group, non-AHs group, and healthy control group).</td></tr>
<tr><td colspan="3">No difference in IFG for differing scores in AHs severity</td></tr>
<tr><td rowspan="2">Bird et al (2010)</td><td colspan="3">Bilateral increase in IFG during VMI (relative to baseline)</td></tr>
<tr><td colspan="3">**Increase in right IFG greater during imagining scenes with more colour complexity that required greater effort to generate.**</td></tr>
<tr><td rowspan="2">Diederen et al (2010)</td><td colspan="3">Bilateral increase in IFG during AH(v) (relative to baseline)</td></tr>
<tr><td colspan="3">Decrease in right IFG prior to AH(v) (relative to baseline)</td></tr>
<tr><td rowspan="2">Escartí (2010)</td><td colspan="3">Increase in IFG for AHs group for task-related components of interest</td></tr>
<tr><td colspan="3">No difference in IFG between AH(v) group and either non-AH(v) group or control group</td></tr>
<tr><td rowspan="2">Korsnes (2010)</td><td colspan="3">Bilateral increase in IFG while doing listening task for both patient (epilepsy with AHs) and control groups</td></tr>
<tr><td colspan="3">*Bilateral increase in IFG less in the patient group (epilepsy with AHs) than in control group.*</td></tr>
<tr><td>Vercammen et al (2010)</td><td></td><td colspan="2">*Connectivity between the right IFG and the left TPJ less in AH(v)-group than in control subjects*</td></tr>
<tr><td rowspan="2">Wais (2010)</td><td colspan="3">**Left IFG (particularly the pars triangularis) connectivity with other ROI (MOG and hippocampus) greater during the experience of VMI (relative to baseline).**</td></tr>
<tr><td colspan="3">*Left IFG (particularly the pars triangularis) connectivity with other ROI less during VMI impeded by distracting visual stimuli.*</td></tr>
<tr><td rowspan="2">Weiler et al (2010)</td><td>Increase in IFG during VMI task (relative to baseline)</td><td colspan="2"></td></tr>
<tr><td>**Increase in IFG during VMI task greater during anticipatory imagery than during memory imagery.**</td><td colspan="2"></td></tr>
<tr><td rowspan="4">Hoffman et al (2011)</td><td colspan="3">**Connectivity between the left IFG and the left STG greater for AH(v) patient group than for non-AH(v) patient group**</td></tr>
<tr><td colspan="3">No difference in connectivity between the left IFG and left STG for AH(v) group and control group</td></tr>
<tr><td>*Connectivity between the left IFG (BA47) and left STG less for patient groups (both AH(v) and non-AH(v)) than in control group*</td><td colspan="2"></td></tr>
<tr><td colspan="3">**Cortico-striatal connectivity (between the left IFG, left STG, and the putamen) greater in AH(v) group than in non-AH(v) patient group and non-patient controls**</td></tr>
<tr><td rowspan="2">Vercammen et al (2011)</td><td colspan="3">No difference correlated to SRH, frequency, or general severity, for IFG during use of 'inner speech' (relative to baseline) in AH(v) subjects</td></tr>
<tr><td></td><td>Decrease in left IFG during use of 'inner speech' (relative to baseline)</td><td></td></tr>
</table>

	INFERIOR FRONTAL GYRUS (IFG)		
		correlates with higher scores in AH(v) loudness	
	No difference for IFG for AH(v) subjects during 'inner speech' task and 'semantic control task'		
Doucet (2012)	*IFG connectivity with other ROI (occipital) less with longer experiences of VMI than of language-based thought*		
	IFG connectivity with other ROI (sensory areas) less with longer experiences of either VMI or language-based thought.		
	IFG connectivity with other ROI (DMN) less with longer experiences of either VMI or language-based thought.		
Sommer (2012)	*Right IFG connectivity with another ROI (right DLPC) less in AH(v) group than in control group*		
	Right IFG connectivity with another ROI (PHG) greater in AH(v) group than in control group		
		Left IFG (frontal operculum) connectivity with another ROI (left STG) less in AH(v) group than in control group	
Slotnick et al (2012)			Increase in left IFG during VMI memory task (relative to baseline)
			No difference for IFG during VMI memory task and non-MI memory task
Ćurčić-Blake et al (2012)		*Interhemispheric connectivity of IFG (right to left) less in AH(v) group than control group:*	
Diederen et al (2013)		**Connectivity between right IFG and left PHG greater in (non-patient) AH(v) group than in controls**	
		Connectivity between left STG and right IFG greater in (non-patient) AH(v) group than controls (with control group showing less connectivity between these regions while AH(v) group showed no change).	
Koeda (2013)	Positive correlation between PANSS scores (for AH(v)-prone schizophrenia) and increase in left IFG while doing judgement task		
	NB: Increase in IFG greater while doing favourability judgement task (FJT) than gender-differentiation task (GDT) in both groups (no difference)		
Zvyagintsev et al (2013)	Bilateral increase in IFG during VMI (relative to baseline)		
	Bilateral increase in IFG during AMI(v) (relative to baseline)		
	Increase in right IFG during AMI(v) greater than during VMI		
	Increase in IFG during AMI(v) & VMI (relative to baseline) greater with higher 'vividness' scores		
	Increase in left IFG greater for high vivid, than low vivid VMI		
	Increases in right IFG greater for high vivid, than low vivid, AMI(v)		
van Lutterveld (2014)	**No difference: IFG activity in AH(v) group (greater than non-AH(v) group) hypothesized but not observed**		

Table 15: Summary of analysis for IPL as a region of interest (supplementary table)

<table>
<tr><th></th><th colspan="4">INFERIOR PARIETAL LOBULE (IPL)</th></tr>
<tr><td>*Neuro-anatomical Terms*</td><td colspan="2">**Supramarginal Gyrus (SG)**</td><td colspan="2">**Angular Gyrus (AG)**</td></tr>
<tr><td>*Brodmann Areas*</td><td colspan="2">BA 40</td><td colspan="2">BA39</td></tr>
<tr><td rowspan="2">*Additional Structural Terms*</td><td colspan="2">Anterior part of the IPL</td><td colspan="2">Posterior (or middle) part of the IPL</td></tr>
<tr><td>Anterior part of SG (SGa)</td><td>Posterior part of SG (SGp)</td><td>Anterior part of AG</td><td>Posterior part of AG</td></tr>
<tr><td>*Functional Terms*</td><td></td><td></td><td colspan="2">Part of Wernicke's Area and the Default Mode Network (DMN)</td></tr>
<tr><td rowspan="3">Ganis 2004</td><td colspan="4">Increase in bilateral IPL during VMI (compared to baseline)</td></tr>
<tr><td colspan="2">Decrease in cluster within right IPL during VMI (compared to baseline)</td><td colspan="2">Increase in bilateral IPL during VMI (compared to baseline)</td></tr>
<tr><td colspan="4">No difference in IPL activity patterns between VMI and perception conditions (each relative to fixation baseline)</td></tr>
<tr><td rowspan="4">Just 2004</td><td colspan="4">Increase in IPL activity during imagery task (involving VMI and possibly AMI) relative to fixation baseline</td></tr>
<tr><td colspan="4">No difference in IPL activity (compared to baseline) between imagery task (involving VMI and possibly AMI) than non-imagery task.</td></tr>
<tr><td colspan="4">**Connectivity between IPL and STG greater during imagery (VMI and possibly AMI) task than during non-imagery task**</td></tr>
<tr><td colspan="4">**Connectivity between IPL and the interparietal sulcus greater during imagery (VMI and possibly AMI) task than during non-imagery task**</td></tr>
<tr><td rowspan="2">Sato et al 2004</td><td colspan="4">Increase in bilateral IPL during AMI(v) [relative to baseline]</td></tr>
<tr><td colspan="2">Peak increase in right IPL during AMI(v) [relative to baseline]</td><td colspan="2"></td></tr>
<tr><td>Stebbins 2004</td><td colspan="2">**Increase in IPL activity for PD patients during visual-task [relative to baseline of no-visual stimuli] greater in Hs group than non-Hs group**</td><td colspan="2"></td></tr>
<tr><td rowspan="2">Rudner 2005</td><td colspan="4">Increase in right IPL during AMI(v) recognition & AMI(v) manipulation [relative to baseline]</td></tr>
<tr><td colspan="4">**Increase in bilateral IPL greater during manipulation of AMI(v) than during the generation/recognition of AMI(v)**</td></tr>
<tr><td rowspan="5">Kana 2006</td><td colspan="4">NB: Increase in IPL during non-imagery task [relative to baseline] in ASD patients & healthy subjects</td></tr>
<tr><td colspan="4">*NB: Increase in IPL during non-imagery task less in healthy subject group than in ASD patients.*</td></tr>
<tr><td colspan="4">Increase in IPL during VMI [relative to baseline] in healthy subjects</td></tr>
<tr><td colspan="4">Increase in IPL during VMI task [relative to baseline] in ASD patients</td></tr>
<tr><td colspan="2"></td><td colspan="2">**Increase in left IPL greater during VMI task greater in healthy subject group than in ASD patient group.**</td></tr>
<tr><td rowspan="2">Butler et al 2006</td><td colspan="2">Increase in left IPL during VMI [relative to baseline]</td><td colspan="2">Increase in bilateral IPL during VMI [relative to baseline]</td></tr>
<tr><td colspan="2"></td><td colspan="2">**Increase in right IPL during VMI greater in women then in men**</td></tr>
<tr><td>Hoffman et al 2007</td><td colspan="2">Increase in IPL during AH(v) [relative to baseline]</td><td colspan="2"></td></tr>
</table>

	INFERIOR PARIETAL LOBULE (IPL)		
Zhang 2008a (Investigation…)	No difference in IPL in response to unfamiliar voice (compared to familiar voices) for AH(v) patients		
	NB: Increase in right IPL in response to unfamiliar voices (compared to familiar voices) in non-hallucinating subjects only		
Zhang 2008b (Relationship…)	**Increase in IPL [while doing perception takes with stimuli presented on left] greater for AH(v) group than non-Hs group**		
			Increase in IPL (while doing perception tasks with stimuli presented on right) greater for AH(v) group than non-Hs group
Wible 2009	Increase in IPL while Hs group undertook a memory task [relative to baseline]		
	Increase in IPL (for doing a memory task [relative to baseline]) less in Hs group than in non-Hs patient group		
	No correlation between IPL activity pattern and reported severity of Hs		
Guillot 2009	Increase in IPL bilaterally during VMI [relative to baseline]		Increase in right IPL during VMI [relative to baseline]
	Increase in IPL less during VMI than kinaesthetic imagery	**Increase in IPL greater during VMI than during kinaesthetic imagery**	
Bird 2010	Increase in left IPL activity during VMI [relative to baseline]		Increase in bilateral IPL activity during VMI [relative to baseline]
	Increases in lateral IPL activity during VMI correlated with increases in the greater reported vividness of VMI		
	Greater connectivity between bilateral IPL and MFG correlated with accuracy in VMI task in both groups		
	No difference in connectivity between IPL and MFG for VMI task between groups		
	Connectivity between IPL and PIVC for VMI task greater in men than in women		
Diederen 2010	Increase in bilateral IPL during AH(v) [relative to baseline]		
Weiler 2010	Increase in right IPL activity during manipulation of VMI [relative to baseline]		
	Increase in right SG activity (relative to baseline) during manipulation of VMI in memory greater than manipulation of anticipatory VMI		Increase in right AG activity [relative to baseline] during manipulation of VMI in memory and in anticipation.
Kaas2010	Increase in IPL during VMI [relative to baseline]		
	Greater connectivity (directed influence) from left IPL to hMT/V5+ during VMI of motion [relative to baseline (of auditory stimuli)]		
Vercammen 2010			*Connectivity between left IPL and IFG less in Hs group than controls*
			Less connectivity between left IPL and the anterior cingulate correlated with: AHRS severity, reality, and attention scores.
Vercammen 2011			Decrease in left IPL during use of 'inner speech' (relative to baseline) correlates with higher scores in AH(v) loudness
			No difference correlated to SRH (reality), frequency, or general severity,

	INFERIOR PARIETAL LOBULE (IPL)	
		for IPL during use of 'inner speech' (relative to baseline) in AH(v) subjects
Slotnick 2012		Increase in IPL during VMI [relative to baseline]
		Increase in IPL during VMI less than during (non-imagery based) memory
Doucet 2012	No difference in IPL connectivity with other ROI (IFG/MFG) for time experiencing VMI as compared to language-based thought	
Sommer 2012	*Left IPL connectivity with another ROI (left STG) less in AH(v) group than in control group*	
	No difference in IPL-STG connectivity during Hs periods compared to non-Hs periods	
Zvyagintsev 2013	No difference in activity within the right IPL during both VMI & AMI [relative to baseline]	Increase in left IPL activity during both VMI & AMI [each relative to baseline]
	Increase in right IPL activity compared to baseline greater during VMI than during AMI	No difference between activity during VMI & AMI
Koeda 2013	**Increase in right IPL greater in AH(v) patients then controls.**	
	Increase in right IPL greater when PANSS scores higher	
	Increase in right IPL greater when AH(v)s severity scores higher	
Yao 2014	Co-activation between IPL and other DMN regions during resting-state	
	No difference in right IPL activity increase between patients with VHs and healthy controls	
	No difference in right IPL activity increase between patients with and without VHs	

Table 16: Summary of analysis for MFG as a region of interest (supplementary table)

	MIDDLE FRONTAL GYRUS (MFG)					
Neuro-anatomical Terms	**Gyrus frontalis medius / Intermediate frontal gyrus**					
Brodmann Areas	BA11	BA46 (also see IFG)	BA10	BA9	BA6	BA8
Additional Structural Terms	Polar part of MFG	Anterior part of MFG		Middle part of MFG	Posterior part of MFG	borderline MFG area
Functional Terms					Frontal Eye Field	
Just et al 2004					Increase in MFG activity within the FEF during imagery task (involving VMI and possibly AMI) compared to baseline	
					Increase in MFG activity (compared to baseline) greater during an imagery task (involving VMI and possibly AMI) than a non-imagery task.	
					Connectivity between MFG and STG was less during an imagery task (involving VMI and possibly AMI) than a non-imagery task.	
					Connectivity between MFG and the interparietal sulcus area greater during an imagery task (involving VMI and possibly AMI) than a non-imagery task.	
Sato et al 2004		Increase in MFG during AMI(v) (VT task relative to baseline) bilaterally, with local maxima in BA 6 (as an extension from the IFG activity in the left, and in its own right on the right).				

<table>
<tr><th></th><th colspan="5">MIDDLE FRONTAL GYRUS (MFG)</th></tr>
<tr><td rowspan="2">Ganis et al 2004</td><td rowspan="2"></td><td colspan="3">Increase in bilateral MFG during VMI (compared to baseline)</td><td></td></tr>
<tr><td colspan="3">No difference between MFG during VMI or for Visual Perception (each compared to baseline)</td><td></td></tr>
<tr><td rowspan="2">Mechelli 2004</td><td colspan="5">Increase in 'mid-frontal' area [MFG activity] during VMI (relative to baseline)</td></tr>
<tr><td colspan="5">Connectivity of 'mid-frontal' demonstrating different top-down mechanisms depending on content imaged</td></tr>
<tr><td rowspan="2">Rudner et al 2005</td><td></td><td>Increase in left MFG during AMI(v) recognition & AMI(v) manipulation (each relative to baseline)</td><td colspan="3"></td></tr>
<tr><td></td><td>Increase in left MFG greater during manipulation of AMI(v) than during the generation/recognition of AMI(v).</td><td colspan="3"></td></tr>
<tr><td rowspan="2">Butler et al 2006</td><td rowspan="2" colspan="3"></td><td>Increase in bilateral MFG during VMI (compared to baseline)</td><td rowspan="2"></td></tr>
<tr><td>Degree of increase in left MFG during VMI correlated with accuracy abilities in mental rotation (in female but not male subjects)</td></tr>
<tr><td rowspan="5">Kana et al 2006</td><td colspan="5">Increase in MFG during VMI task (relative to baseline) in healthy subjects</td></tr>
<tr><td></td><td colspan="3">Increase in MFG during VMI task greater than for semantic-task in healthy subjects</td><td></td></tr>
<tr><td colspan="5">Increase in MFG during VMI task (relative to baseline) in subjects with autism (patients)</td></tr>
<tr><td rowspan="2">Increase in right MFG and VMI task greater in healthy group than in patient group</td><td colspan="3">No difference in MFG during VMI task and for semantic task in subjects with autism (taken as evidence that for autistic patients semantic-task involves VMI)</td><td rowspan="2">Increase in left MFG for VMI task greater in healthy subject group than in patient group</td></tr>
<tr><td></td><td>Increase in left MFG for VMI task greater in healthy control group than in patient group</td><td>Increase in left MFG for semantic-task less in healthy control group than in patient group</td></tr>
</table>

	MIDDLE FRONTAL GYRUS (MFG)					
Hoffman et al 2007		Bilateral increase in MFG bilaterally during AH(v) (relative to baseline)				
Zhang et al 2008a				**Increase in right MFG in response to familiar voices (greater than unfamiliar voices) only in AH(v) group**		
Zhang et al 2008b			*Increase in right MFG less for AH(v) patient group than healthy group [while doing perception task with stimuli presented on right]*		*Increase in right MFG less for AH(v) patient group than healthy group [while doing perception tasks with stimuli presented on right]*	
Ramírez-Ruiz et al 2008		No difference in MFG during face-detection task and control task in either VHs group or healthy group			*Increased activity in the left MFG in face-detection task (compared to baseline) less in VHs subjects than in non-Hs patients*	*Increased activity in the right MFG in face-detection task (compared to baseline) less in VHs patients than non-Hs patients*
		NB: MFG activity in non-Hs patient group greater for face detection task than control task				

<table>
<tr><th></th><th colspan="6">MIDDLE FRONTAL GYRUS (MFG)</th></tr>
<tr><td rowspan="2">Weiler et al 2010</td><td rowspan="2"></td><td rowspan="2">Increase in bilateral MFG during the construction & elaboration phase of both 'past' and 'future' MI conditions (compared to baseline)</td><td></td><td colspan="3">Increase in right MFG during the construction phase of both 'past' and 'future' MI conditions (compared to baseline)</td></tr>
<tr><td colspan="2">Increase in left MFG during the elaboration phase of both 'past' and 'future' MI conditions (compared to baseline)</td><td colspan="2">Increase in right MFG during the elaboration phase of both 'past' and 'future' MI conditions (compared to baseline)</td></tr>
<tr><td rowspan="2">Diederen et al 2010</td><td rowspan="2"></td><td colspan="4">Decrease in left MFG activity preceding hallucinations (relative to baseline)</td><td rowspan="2"></td></tr>
<tr><td colspan="4">Increase in MFG (bilaterally, with local maxima in right) during AVHs (relative to baseline)</td></tr>
<tr><td>Diekhof et al 2011</td><td></td><td colspan="4">Connectivity (degree of positive coupling) between MFG (bilaterally) and left FG during anticipatory VMI predicted accuracy of subsequent perceptual judgement</td><td></td></tr>
<tr><td>Hoffman et al 2011</td><td></td><td>Connectivity between left BA46 and other regions greater in AH(v) patient group than comparison groups. See IFG analysis for further detail</td><td colspan="4"></td></tr>
<tr><td rowspan="3">Doucet et al 2012</td><td rowspan="3"></td><td colspan="4">MFG connectivity with other ROI (occipital) less with longer experiences of VMI than of language-based thought</td><td rowspan="3"></td></tr>
<tr><td colspan="4">MFG connectivity with other ROI (sensory areas) less with longer experiences of either VMI or language-based thought.</td></tr>
<tr><td colspan="4">MFG connectivity with other ROI (DMN) less with longer experiences of either VMI or language-based thought.</td></tr>
<tr><td rowspan="2">de Borst et al 2012</td><td rowspan="2"></td><td colspan="4">Increase in bilateral MFG during VMI (compared to baseline)</td><td rowspan="2"></td></tr>
<tr><td colspan="4">Steep increase in right MFG during early stage of VMI (compared to baseline)</td></tr>
<tr><td>Slotnick et al 2012</td><td colspan="3"></td><td>Increase in MFG activity during VMI (compared to baseline)</td><td colspan="2"></td></tr>
</table>

	MIDDLE FRONTAL GYRUS (MFG)			
			NB: Increase in MFG activity during non-imagery memory (compared to baseline)	
			No difference between increase in MFG activity between VMI and non-imagery memory	
Zvyagintsev et al 2012	Increase in left MFG activity during AMI [relative to baseline]			Increase in left MFG activity during AMI [relative to baseline]
	Increase in left MFG activity during VMI [relative to baseline]			Increase in left MFG activity during VMI [relative to baseline]
		Increase in left MFG activity greater during AMI than VMI		**Increase in bilateral MFG activity greater during VMI than AMI**
Koeda et al 2013				NB: Increase in MFG in all subjects when preforming perception-judgement tasks [relative to baseline]

	MIDDLE FRONTAL GYRUS (MFG)			
		Increase in right MFG correlated with higher score in patient PNASS scores (for AH(v)-prone schizophrenia) and in Hallucination Severity scores	**Increase in MFG (bilaterally) greater in AH(v)-prone patient-group than in control-group**	
Goetz et al 2014				*Increase in MFG activity less during VHs than during non-hallucinating period baseline.*
Shine et al 2014			NB: Increase in MFG activity when VHs Parkinson's patients process visual stimuli	
			NB: Increase in MFG activity when non-Hs Parkinson's patients process visual stimuli	
			Increase in MFG activity while doing visual task less in patients with VHs than in patients without.	
Yao 2014		*NB: Increase in MFG less in non-Hs patients than healthy controls*		*NB: Increase in MFG less in non-Hs patients than healthy controls*
		No difference in the increase in MFG activity between patients with VHs and healthy controls		No difference in the increase in MFG activity between patients with VHs and healthy controls

	MIDDLE FRONTAL GYRUS (MFG)			
		No correlation found between severity of VHs and the connectivity between MFG and other ROI		No correlation found between severity of VHs and the connectivity between MFG and other ROI
		Connectivity between the right MFG and the bilateral posterior cingulate gyrus greater in PD patients with VHs than those without.		**Connectivit y between the right MFG and the bilateral posterior cingulate gyrus greater in PD patients with VHs than those without.**