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Are noetic feelings embodied? The case for embodied metacognition

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ABSTRACT

One routinely undergoes a noetic feeling (also called "metacognitive feeling" or "epistemic feeling"), the so-called "feeling of knowing", whenever trying to recall a person's name. One *feels* the name is known despite being unable to recall it. Other experiences also fall under this category, e.g., the tip-of-the-tongue experience, the feeling of confidence. A distinguishing characteristic of noetic feelings is how they are crucially related to the facts we know, so much so that the activation of semantic memory can easily result in the production of noetic feelings – a regularity that memory research has often exploited. And yet little is known about the mechanism that produces noetic feelings. Is it solely brain-based or does it depend upon the extracerebral body for its production of feelings? To arrive at an answer, various studies in metamemory research will be analyzed to determine what ought to be made of the mechanism responsible for noetic feelings. I argue that evidence suggests that it relies upon extracerebral processes, in particular cardiovascular processes, the result being support for an embodied view of metacognition.

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1. Introduction

Imagine being given a list of names to memorize for subsequent recollection, being presented with a name later on, and having to judge whether it was among those on the previously studied list. One of two mental episodes will typically occur. You might remember the *previous experience* of memorizing the name or you might look at the name and be struck with a *feeling* that the name is familiar or known. This is an illustration of the well-corroborated aspect of memory called the "remember-know phenomenon" introduced by Tulving (1985) in support of the distinction between two systems of memory, respectively episodic and semantic memory. In contemporary memory research, skepticism has emerged surrounding the systems theory of memory (Michaelian, 2016), but for the purposes of our

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discussion, semantic memory need only serve as a shorthand for those mnemonic mechanisms involved in the recollection or judgment of facts, the activation of which is commonly associated with certain noetic feelings, specifically the feeling of knowing or the feeling of familiarity (for present purposes, these feelings can be considered equivalent).

Since Tulving (1972) introduced this distinction in his seminal work, episodic and semantic memory have been widely accepted as two distinct and primary forms of memory, so much so that it has been called the "standard taxonomy of memory" (Michaelian & Sutton, 2017). Essentially, episodic memory is the system that stores and retrieves first-hand experiences, while semantic memory is the system that deals in facts about the world. In the philosophy of mind and cognition, much has been said about episodic memory, particularly how best to conceive of it as distinct from semantic memory, by appealing to, e.g., the phenomenological property of pastness (Martin, 2001). Here, questions about the role of the extracerebral body in episodic memory are generally met with a consensus. This is because the general assumption is that episodic memory is intrinsically tied to emotional experience, which depends upon the extracerebral body. For example, evoking Kant's famous declaration, de Sousa (2017) writes about episodic memory stating, "Memory, we might say, would be empty without emotion, and emotion blind without memory" (p. 163).

Regarding semantic memory, however, no such consensus exists, and it remains unclear what should be made of the brain-body relationship if there even be one (henceforth, "body" and "bodily" will refer to the *extracerebral* body). Prominent models do not appeal to feelings, emotions, affective episodes, or bodily processes, often positing only associative semantic networks comprised of various mnemonic nodes and relationships between nodes in order to account for the mechanisms of semantic memory (e.g., Jacoby et al., 1989; Reder et al., 2000).

In what follows, the noetic feelings of semantic memory will be discussed (except when mentioned explicitly, by "noetic feelings" I mean only those noetic feelings associated with semantic memory) and reasons for and against construing the mechanism that produces noetic feelings as embodied will be determined by analyzing the results of metacognition research, as well as the results of studies in affective psychology that reveal an intricate relationship between metacognition and interoception (i.e., the capacity to sense and interpret, both consciously and unconsciously, bodily afferents). Essentially, the overarching claim is that any explanation of noetic feelings that leaves out the extracerebral body foregoes an exhaustive explanation of how noetic feelings fulfill their role in the cognitive economy.

In line with much of the literature on metacognition (Beran et al., 2012), I will assume for this discussion that noetic feelings are metacognitive, in that their role in the cognitive economy is to guide the unfolding thought

process (Proust, 2013). That said, there is an unresolved controversy about whether noetic feelings are properly metacognitive or metarepresentational (Arango-muñoz, 2018; Carruthers, 2016). This controversy concerns whether noetic feelings are second order, that is, whether they represent internal cognitive states (and so are *meta*cognitive) or merely first order, and so represent external features of the world. As such, this debate is orthogonal to what is claimed here. Even if noetic feelings characterize first-order states, they may nonetheless serve as crucial enablers and facilitators of the unfolding thought process.[1]

Thus, it helps to consider Tulving's (1985) tripartite distinction between anoetic, noetic, and autonoetic feelings to make sense of what qualifies a noetic feeling as metacognitive, three feelings which are not typically distinguished along metacognitive or metarepresentational lines (e.g., Metcalfe and Son (2012) argue that all three are implicitly metacognitive). While *a*noetic feelings carry information solely about aspects of the present environment (both the external and the internal (bodily) environment), *auto*noetic feelings carry information about the subject herself explicitly. Thus, fitting neatly into this framework, noetic feelings carry information about entities (states, properties, processes, actions, events) that we would be happy to classify as mental[2] (beliefs, judgments, intentions, concepts, perceptions, memories, experiences, etc.), while *not* carrying information about the self explicitly. Noetic feelings can thus be thought of as metacognitive in the sense of *implicitly informing subjects about mental entities and their properties*. But for reasons having to do with their relationship to explicit forms of metacognition, a connection which I unfortunately cannot properly do justice to here, I have chosen to articulate the metacognitive status of noetic feelings by appealing to their role in the cognitive economy as enablers and facilitators of the unfolding thought process.

The aim of the present proposal is to provide strong support for embodied metacognition, akin to proposals in the wider family of embodied cognition (Clark, 2007; Gallagher, 2006; Hurley, 1998; Shapiro, 2019). So, let me briefly say why we should care whether metacognition is embodied. As I understand it for the purpose of this proposal, embodiment is about an extracerebral body being responsible for handling some of the problem-solving work that would otherwise be performed by a central and cerebral process. Essentially, embodiment is a claim that the extracerebral body ought to be construed as part of the cognitive process, serving as output, but also responsible for generating input, "cases where we confront a recognizably cognitive process, running in some agent, that creates outputs that, recycled as inputs, drive the cognitive process along" (Clark, 2007, p. 185).

An example of this is the role of bodily gestures in the unfolding of thought (Clark, 2008; McNeill, 2005): the extracerebral body serves as input

to the cognitive process, enabling and facilitating the unfolding of thought and generating components that are cognitive in their own right. As we shall see, noetic feelings fulfill an analogous role. Therefore, we ought to care about claims of embodiment, regarding metacognition or otherwise, because, if sound, they contribute to solving a task already cared about, namely, that of providing an exhaustive explanation of the power of cognition to solve problems.

Before continuing, allow me to define some more key terms that will be with us throughout our discussion. From the above definition, weaker or stronger forms of embodiment can emerge, wherein the cognitive process is more or less dependent on the body. As it concerns the proposal that metacognition is embodied, several accounts are at play in the literature. What I label "the weak view" construes the role of the body as drawing attention to metacognitive processing fluency signals (henceforth referred to as "processing fluency" or "fluency"; see below), while "the strong view" sees the body as playing a more significant role in this process, not merely serving to draw attention to metacognitive information, but rather carrying metacognitive information in its own right. Thus, the difference between weak and strong embodiment is described below as a matter of the *intricateness* of the implied brain-body relationship, how tightly interwoven and entangled their relations are (see Section 3.1).

A highly intricate brain-body relationship in metacognition will be argued for by appealing to empirical evidence about noetic feelings that supports a common mechanism between metacognition and interoception. This makes plausible, what I shall call in the spirit of William James (1890), a "neo-Jamesian theory about noetic feelings", namely that what you feel, when feeling noetic feelings, are bodily changes.

This brain-body relationship obtains, I hypothesize, due to how bodily changes index changes in processing fluency. This notion of indexing ought to be read as entailing strong informational correlations between what is doing the representing (the body) and what is being represented (the brain; for indexing, see Recanati, 2012), and it ought to be distinguished from a far more sophisticated mode of representing, wherein something is represented *as* what it is (Burge, 2010). The proposal is thus that certain bodily changes ought to be construed as indexing certain metacognitive changes.

Let's discuss the map of the contested territory. To the west lies a family of conservative views that can be named "the traditional view" (Section 2). Two are prominent in the literature: the "direct view" (Section 2.1) and the "indirect view" (Section 2.2) and both hold that noetic feelings are produced by a mechanism that is solely cerebral. Models based on this view will be criticized for how they imply empirical claims that I argue are false throughout the latter half of this paper; namely, it is false that noetic feelings are

produced by a solely cerebral mechanism, and it is false that noetic feelings are non-embodied feelings.

Meanwhile in the east, a family of liberal upstarts has emerged, emphasizing evidence that exposes the need to appeal to extracerebral processes to account for the mechanism that produces noetic feelings. Call this "the embodied view" (Section 3). Meanwhile, two siblings are in competition with each other: the weak and the strong. After first discussing a condition that would justify claims of strong embodiment (Section 3.1), I discuss the case for weak embodied metacognition (Section 3.2), but I argue in favor of the strong view that advocates for a highly intricate brain-body relationship in metacognition (Section 3.3), such that, bodily changes index metacognitive changes and convey metacognitive information in their own right (Section 3.4). Thereafter, I conclude with a summary and discuss avenues for future research (Section 4).

2. The problem with traditional views of noetic feelings

In this section, the problem with traditional views of noetic feelings will be discussed. As a reminder, the view that noetic feelings are non-embodied amounts to making two problematic empirical claims, one about their underlying mechanism being solely cerebral, and another about the plausibility of a non-embodied kind of feeling. As discussed in the next section (Section 3), evidence suggests these empirical claims are false and should be regarded with skepticism.

2.1 The traditional direct model of noetic feelings

As it is construed here, traditional views aim to explain noetic feelings by appealing to semantic networks of various configurations, often in an effort to account for the "remember-know phenomenon" (Tulving, 1985). Introduced above, this phenomenon is based on an observed discrepancy in mnemonic recall, one which distinguishes the semantic from the episodic system of memory. To predict the remember-know phenomenon, Reder et al. (2000) developed a prominent model that distinguishes between two types of mnemonic nodes: a concept node, which holds lexical information (semantic memory), and an event node, which holds information about the encoding event (episodic memory).

As is common in the literature (Dunlosky & Metcalfe, 2008), Reder et al. describe the "know" response as dependent on the subject undergoing noetic feelings and theorize their production results from "an elevation in base-level activation" of one or more concept nodes (ibid, p. 318). Thus, the production of noetic feelings is explained by appealing to solely cerebral

(specifically, mnemonic) mechanisms, such that no explanans appeals to any bodily process.[3] Though this is only one example, more models with a similar explanatory structure, used to elucidate the mechanisms responsible for the production of noetic feelings, will be discussed below.[4]

Thus, this claim about the status of the mechanism producing noetic feelings as solely cerebral runs counter to contemporary theories in affective psychology about the nature of feelings, and so this claim is potentially false due to how it implies a claim about the non-embodied status of noetic feelings. Relative consensus surrounds the proposal that feelings are one of the central components to emotion (Armony & Vuilleumier, 2013). One such increasingly influential theory is the neo-Jamesian interoception-based theory of emotion, which understands feelings as arising from the internal perception, the *intero*ception, of physiological changes occurring within the body (Tsakiris & De Preester, 2018). Within this framework, feelings are conceptualized as the conscious expression of emotion, so that certain bodily processes play a crucial role in the cognitive economy by making cognitive features salient by producing bodily afferents sensed via interoceptive channels.

That said, proponents of the traditional approach might wish to distinguish two distinct species of feeling, noetic feelings and emotional feelings, with the body playing a crucial role only in the production of the emotional sort.[5] In other words, traditionalists might wish to respond by advocating for an "anti-Jamesian" species of feeling, a solely cerebral, non-embodied ("noetic") feeling. But such a claim stands in need of empirical support, and the emerging evidence suggests this position ought to be regarded with skepticism (see Section 3). Before this evidence can be discussed, however, we ought to examine one key strategy that a proponent of the traditional view might pursue to bolster the case for an anti-Jamesian feeling, one which involves an appeal to fluency, a central theme that will be with us throughout our discussion.

2.2 The traditional indirect model with processing fluency

Distinct from Reder et al.'s direct model of noetic feelings above, Jacoby et al. (1989) widely influential indirect model appeals to fluency as an intermediary between noetic feelings and their underlying mechanism. Defined as "the content-independent speed and accuracy of ongoing processing (Topolinski & Strack, 2009a, 1468), so-called "metacognitive processing fluency" is a fundamental component to many prominent models explaining metacognition. To better grasp exactly how this appeal has the potential to bolster the traditional view, it will be worth discussing the technical details.

Jacoby and Whitehouse (1989) conducted experiments involving word recognition that consisted of two phases and two conditions, experiments which echo Tulving's original studies discussed above. In the first phase, subjects were presented with a list of words to be studied. In the second phase, subjects were presented with a single test-word and had to judge whether it had been on the list. Crucially, sometimes the presentation of a test-word was preceded by the presentation of a context-word, which was either the same as the test-word, different from it, or consisted of a string of nonsense characters (such as "&&&&&"). Each experiment involved two conditions: the unaware condition, in which the context-word was visually masked, and the aware condition, in which the duration of the presentation of the context-word was increased and subjects were told about it in advance.

Jacoby and Whitehouse found surprising results. If a masked context-word was the same as the test-word in the unaware condition, subjects were more likely to report erroneously the test-word as previously studied, though this error was not made if subjects were in the aware condition. Jacoby and Whitehouse stress that these experiments ought not to be construed as demonstrating mere priming effects (i.e., the well-known phenomenon, wherein the presentation of one stimulus, below the threshold of conscious awareness, enhances the processing of another). This is because, highly relevant for our discussion, rather than e.g., demonstrating the increased speed by which subjects recognize primed words, these experiments asked subjects to judge whether a test-word was old or new, which Jacoby and Whitehouse interpret as involving the noetic feeling of familiarity, which itself "rests on an attribution or inference about the source of effects on processing" (ibid, p. 127).

Jacoby and Whitehouse account for the production of noetic feelings by appealing to specific activation patterns in neural populations (i.e., those occurring in, between, or across concept nodes) theorized to produce fluency, which subjects infer, with the aid of a cognitive appraisal, as the familiarity of the stimulus. Thus, noetic feelings are conceptualized as appraised fluency signals. Crucially, Jacoby and Whitehouse theorize that fluency signals are produced solely by patterns of neuronal activation, a process that does not depend upon the body in any significant way, a view about fluency that is still widely held (for a review, see Alter & Oppenheimer, 2009).[6]

If such an account is accepted as sufficiently explaining the mechanism behind the production of noetic feelings, and noetic feelings are conceptualized as feelings in the spirit of affective psychology, the soundness of this account will depend upon a distinction between cerebrally-produced feelings, on the one hand, and extracerebral-produced feelings, on the other.

Thus, implicit in this view is an empirical claim about the mechanism behind noetic feelings, an empirical claim which, evidence suggests, is likely false (see Section 3).

Below I argue the traditional view ought to be augmented to model the whole process, including the extracerebral body and its role in producing noetic feelings. In this regard, two avenues for augmentation will be discussed. First, one might provide a convincing case that processing fluency signals impinge upon a subject's core affect state which further produces bodily afferents (i.e., noetic feelings) that draw the subject's attention to the information provided by the metacognitive processing fluency signals. This is the weak embodied view, and it will be discussed first (Section 3.2). Otherwise, one could argue for a stronger brain-body relationship in metacognition by appealing to how bodily afferents make *information about fluency* accessible in their own right (Section 3.3). This is the strong embodied view, and it will be discussed and argued for last (Section 3.4).

3. The embodied metacognition approach

As I interpret them, proponents of the embodied view, whether weak or strong, maintain a neo-Jamesian theory about noetic feelings, maintaining that noetic feelings ultimately result from the interoception of bodily afferents. Furthermore, this theory implies embodied metacognition, since extracerebral processes play a critical role in explaining how noetic feelings operate in the cognitive economy, serving as both output and input to the unfolding thought process. In what follows, evidence in favor of holding an embodied view will be discussed.

3.1 Condition for strong embodiment

Before findings from interoception-based research in metacognition can be introduced, it must be clarified what it would mean for a metacognitive mechanism to be embodied. As already mentioned, it is assumed, in line with much of the literature on metacognition, that the cognitive role of noetic feelings is to guide the unfolding thought process. This means, following from considerations above about the nature of embodiment, the goal is to show that bodily afferents are responsible for noetic feelings realizing this cognitive role. To argue for this, I interpret empirical evidence that demonstrates how the production of noetic feelings depends upon an intricate interface between the brain and the body, a common mechanism between metacognition and interoception, in which, plausibly, information about fluency is indexed by bodily changes and made consciously accessible through the interoception of bodily afferents.

To be clear, several views below are embodied views. This is because, they imply that the extracerebral body is an essential part of the problem-solving process due to how changes in fluency cause changes in physiological arousal (output), which, in turn, produces noetic feelings that serve as guides (input) to the subject's unfolding thought process. In other words, even the weak view holds that bodily processes must be appealed to in order to account for how metacognitive processing fluency becomes consciously accessible.

To distinguish the strong from the weak view, consider this analogy. According to the weak view, while bodily afferents draw your attention to metacognitive information, they do not make this information accessible in their own right. Here, bodily afferents act like a security alarm that sounds whenever a break-in occurs. If you wish to know whether the break-in is at the front or at the back of the house (the first of two dimensions: fluent or disfluent; see below), or if you wish to know the severity of the break-in, e.g., how many intruders there are (the second dimension: how fluent/disfluent), you will not appeal to the alarm, as it clearly does not represent this information, but rather to a security monitor that displays camera-feeds from the appropriate locations. The visual information at the security monitor is analogous to the (non-embodied, "genuine") fluency signal posited by the weak view, which the (embodied) alarm merely draws your attention to. This is in stark contrast to the strong view that claims that bodily afferents carry metacognitive information in their own right, so that, sticking with the same analogy, the alarm, itself, provides the information that the security monitor would: the pitch (bodily valence) of the alarm represents the location of the intrusion, while the volume (bodily arousal) represents its severity.[7]

It is as though the relationship obtaining between fluency and physiological arousal can be thought of as a process of translation. In this respect, the language of metacognition is written in patterns of electrochemical activity that describe communication across neuronal populations as fluently or not fluently processed and to some degree, high or low (or somewhere in between). If it is correct to say that this process is embodied, the source language of cerebral activity will need to be translated, as it were, into the target language of the extracerebral body, that of emotional affect, i.e., becoming bodily afferents that serve as guides to the unfolding thought process.[8]

Intuitively, this process of translation ought to be adaptive because of how emotion reflects one crucial component to Nature's solution to the problem of action, i.e., the problem of what exactly to do now, at this very moment, given so many possibilities (Railton, 2017). The information carried by fluency will thus be all the more effective in guiding behavior if it is recast in bodily valence and arousal. In this respect, stronger claims

about embodiment are those that advocate for more faithful translations from the language of the brain to that of the body.

Below I interpret the weak view as a claim about a weakly intricate brain-body relationship obtaining between fluency and bodily afferents (Section 3.2). In particular, the weak view appeals to bodily afferents to explain how fluency, a solely cerebral signal, becomes accessible to the subject, though it is unclear whether these studies provide evidence to support this view (see below). In other words, the weak view holds that bodily afferents index a singular piece of information, the *accessibility* of metacognitive information, and so do not make metacognitive information accessible in their own right.

Meanwhile, the strong view is a claim about a highly intricate relationship obtaining between the brain and the body in metacognition (Section 3.3). Here, fluency/disfluency, and its degrees, are made accessible to the subject by first becoming translated into bodily valence and arousal, which the subject senses through interoceptive channels, due to how metacognition and interoception are underlaid by a common mechanism. In other words, the strong view holds that bodily afferents index metacognitive information in two dimensions (1. fluent/disfluent and 2. how fluent/disfluent), and so make, in their own right, metacognitive information accessible.

I argue in favor of the strong view by discussing how the empirical evidence points in its favor, suggesting that bodily afferents index processing fluency (Section 3.4). Of course, if either the weak or the strong view is true, the traditional view, which construes the mechanism responsible for producing noetic feelings as independent of the extracerebral body, is false. So, in building the case for either embodied view, I also make the case that the traditional view should be regarded with skepticism.

3.2 Weak embodied metacognition

Perhaps the first instance of an embodied view comes from a study conducted by Goldinger and Hansen (2005) that found that a subliminal buzzing (emanating from a subwoofer surreptitiously placed under the subject's chair) would enhance feelings of familiarity, which showed that subjects under the buzz's influence were more likely to report a stimulus as "old" both correctly and incorrectly (for a discussion of this study and similar studies with respect to the debate about the metacognitive status of noetic feelings, see Arango-muñoz, 2018). Crucially, the buzz was found not only to increase confidence in false alarms, but, moreover, reduce confidence in true positives.

A similar study conducted by Allen et al. (2016) measured the influence of unexpected arousal on confidence reports which are argued to be made

on the basis of subjects undergoing noetic feelings of confidence. They did this by presenting masked disgust-cues in advance of a visual discrimination task of variable sensory precision: stimuli were either precise (and so easy to discriminate) or blurry (and so hard to discriminate). Similar to the study above, subliminal disgust cues were found to decrease confidence in visually precise trials and increase confidence in noisy ones.

Allen and colleagues explain this inverted relationship by appealing to the Bayesian brain hypothesis (Knill & Pouget, 2004), wherein unexpected arousal can be conceived of as counteracting the influence of cognitive processing biases. Such biases are theorized to be computational priors nested deep within the cognitive hierarchy that modulate the influence of sensory information on experience.

If this is correct, Goldinger and Hansen's study could be interpreted to have shown how the subliminal buzzing served to counteract priors about mnemonic processing: under the influence of the subliminal buzz, higher fluency is experienced as indicating an unfamiliar stimulus, while lower fluency indicates a familiar stimulus, a result which Allen and colleagues see as "motivat[ing] a revised view of metacognition as incorporating [priors] about both physiological states and the precision of actual sensory inputs" (ibid, p. 7).

In other words, applying Allen at el.'s gloss yields the proposal that before noetic feelings guide the unfolding thought process, the cognitive system deploys computational priors concerning, not only patterns of mnemonic activity, but also patterns of bodily activity. Bodily information is thus construed as integral to the metacognitive process of determining knowledge, familiarity, confidence, etc.

That said, while this finding clearly establishes Allen and colleagues' view as an embodied one, it is unclear whether the deployment of interoceptive priors can be said to produce bodily afferents that are interoceptively sensed by the subject, signals which indicate the accessibility of metacognitive information (the weak view) or carry metacognitive information in their own right (the strong view). Thus, this, what might be called, "threshold" embodied view solely maintains that the body has an integral role to play in the global process of forming metacognitive judgments.

Progressing toward stronger views, Morris et al. (2008) measured subjects' skin conductance responses (SCR) while reporting either remembering or knowing words that had been previously or not previously studied (see the remember-know phenomenon above). They found that "SCR latencies were significantly longer in response to studied words than in response to non-studied words" (ibid, p. 1384). Due to how previous research shows that SCR latencies increase during attention-demanding tasks (Dawson et al., 2000), Morris et al. interpret these results as providing evidence that noetic feelings "stem from autonomic arousal associated with

cognitive resource allocation" (ibid, p. 1378). Essentially, these researchers propose that noetic feelings are products of the autonomic arousal generated when the central nervous system requires the allocation of additional resources.

Thus, according to Morris and colleagues' view, certain bodily afferents become inferred by the subject with the aid of a cognitive appraisal as indicating an epistemic value, e.g., knowledge, familiarity, confidence, etc. (ibid, p. 1379). As such, bodily afferents are responsible for making the allocation of additional cognitive resources salient to the subject, effectively drawing her attention (like an alarm) to the metacognitive information disclosed by the cognitive appraisal (i.e., the weak view).

That said, while Morris et al.'s view implies a more intricate brain-body interface than that of Goldinger and Hansen's view, as bodily afferents are construed here as making fluency salient, their study stops short of providing evidence of this. It is highly unlikely that SCRs are sensed by the subject and guide her unfolding thought process: the electrodermal activity of SCRs, though often a marker of conscious activity, is not theorized to be consciously accessible (Dawson et al., 2000). Thus, such *unconscious* afferents cannot serve as a kind of alarm, drawing the subject's attention to metacognitive fluency, and so their study does not provide evidence of a weakly intricate brain-body relationship in metacognition.

Moving on to a stronger view, two studies conducted by Köhler's memory lab are highly relevant for our discussion, studies which investigated the relationship between noetic feelings and cardiovascular afferents (Fiacconi et al., 2016, 2017). The first is discussed here and the second in the next section (Section 3.3). In the first study, subjects were given a facial recognition task while their cardiovascular activity was monitored via electrocardiography. This enabled researchers to synchronize the presentation of memory probes to the two phases of the cardiac cycle: systole, when cardiovascular feedback is the strongest, and diastole, when feedback is the weakest.

Fiacconi et al. (2016) found that cardiovascular feedback can influence metacognitive judgments: faces presented during systole were more likely to be judged as old than faces presented during diastole (regardless of whether faces were targets or lures or whether those faces were emotionally laden or neutral in countenance). Crucial to our discussion, this correlation was found only to hold for the "know" response with its associated noetic feelings, suggesting that this result informs about their underlying mechanism.

Though this study provides evidence of an embodied view of metacognition, as cardiovascular feedback might be construed as a somatic marker indicating familiarity (Damasio, 1996), it fails to provide sufficient evidence for holding either a weak or strong view. While the production of cardiovascular feedback is predictive of an increased likelihood that subjects will report

a stimulus as familiar, it is nonetheless unclear whether subjects interoceptively sense the cardiovascular signals produced during systole (specifically, the signals produced by the activation of baroreceptors during ventricular contraction and ejection), and, as such, whether such bodily afferents could serve as an alarm that would draw attention to metacognitive information (or could make metacognitive information accessible in their own right). Similar to SCRs, it is debatable (though less so), whether cardiovascular feedback during systole is conscious. That said, the second study conducted by Köhler's lab (Fiacconi et al., 2017) aimed to remedy this issue, and these results above will be reinterpreted alongside those of the second study to provide evidence for holding a strong embodied view of metacognition (see Section 3.3).

Let us conclude this section with one prominent theory that captures key commonalities between the weak views. Topolinski and Strack (2009b) explain the mechanism behind noetic feelings with reference to a feeling of semantic coherence, a measure of the degree to which disparate words form a semantic whole (e.g., taken together "salt", "deep", and "foam" imply the sea). Though their theory shares crucial features with traditional models already discussed (e.g., involving an appeal to mnemonic nodes connected by links of varying strengths), it differs with respect to the mechanism that produces noetic feelings, such that fluency is thought to trigger an affective response, one that is central to the process by which noetic feelings fulfil their role in the overarching cognitive economy.

In this respect, Topolinski and Strack suggest bodily afferents form an essential part of the process: "This fluency impinges on the current affective state, . . . a diffuse and automatic assessment of hedonically important factors such as the physiological milieu, but also reflect[ing] all the information processing going on" (Topolinski & Strack, 2009a, 1469). Thus, Topolinski and Strack maintain that it is in virtue of changes in physiological arousal that fluency signals become consciously accessible, theorizing that the mechanism underpinning noetic feelings is embodied due to how the extracerebral body serves as both output and input to the cognitive process: the relevant bodily afferents give fluency its affective dimension, making it salient to the subject in the form of noetic feelings that guide the unfolding thought process.

Though this view is indeed an embodied one, it is unclear whether it advocates for a weakly intricate or a highly intricate brain-body interface in metacognition. On the one hand, it suggests that fluency impinges upon the subject's affective state and causes the production of bodily afferents, which, in turn, shape the unfolding thought process. But it is unclear whether bodily afferents satisfy a role over and above that of an alarm that would simply draw attention to the fluency signals. In short, a great deal hinges on what it means for the current affective state to *reflect* "all the information processing going on". This could be read as implying a stronger claim that fluency features are represented by bodily afferents, which, if correct, would

suggest Topolinski and Strack hold a strong view. But the wording is unfortunately too vague to categorize with certainty.

3.3 Strong embodied metacognition

On the basis of recent neuroimaging studies that provide evidence that both metacognition (Chua et al., 2006) and interoception (Critchley, 2002) recruit the insula region, Chua and Bliss-Moreau (2016) investigated whether metacognition and interoception are underpinned by a common mechanism. They found "interoceptive accuracy and metamemory accuracy [. . .] were related such that individuals with higher interoceptive accuracy also had better [metamemory accuracy]" (ibid, p. 155).

Chua and Bliss-Moreau compared subjects' ability to perceive accurately their own heartbeat to their ability to form accurate metacognitive judgments. After a study phase, subjects paired names with faces and then rated their confidence in having chosen the correct name. This is widely referred to as a "judgment of learning" (JOL) (Koriat, 2000). Effectively, Chua and Bliss-Moreau's study provides evidence that the more accurate subjects are in detecting their own heartbeat, the more accurate will be their own evaluation of their cognitive performance, suggesting "both processes rely on a common mechanism" (ibid, p. 156).

Further details surrounding this study will be discussed below, but before doing so, a crucial relationship needs to be clarified. Patently, JOLs are members of a distinct species of mental entity than that of noetic feelings (after all, judgments are not feelings). However, it is safe to interpret, once certain conditions are met, that studies measuring JOLs inform about the mechanism behind the production of noetic feelings. Researchers have argued convincingly that both the casting of JOLs and the production of noetic feelings ultimately rely upon fluency signals and the familiarity of context-relevant cues, resulting in the well-corroborated hypothesis, the "cue-familiarity heuristic" (Metcalfe, 1993; Schwartz, 1994).

On the strength of this hypothesis, one can infer the results of any study designed to inform about the mechanism underpinning JOLs as also informing about the mechanism behind noetic feelings, so long as noetic feelings, which motivate and serve as the basis for JOLs, be distinguished from the JOLs themselves. Below I focus on the process that motivates casting JOLs, which can be safely assumed to involve noetic feelings.

Returning to Chua and Bliss-Moreau's theory, a common mechanism is posited to underpin two capacities, the capacity to detect bodily afferents accurately (interoceptive sensitivity) and the capacity to cast accurate JOLs (metacognition). Thus, Chua and Bliss-Moreau believe that the mechanism enabling the perception of bodily afferents is the same mechanism (or shares crucial cognitive components with the mechanism) that enables the

perception of noetic feelings, so that the mechanism behind noetic feelings ought to be construed as interoceptive.

Though it is less clear whether their study provides evidence that subjects are interoceptively sensing bodily afferents while experiencing noetic feelings, the fact that performance in the interoceptive domain predicts performance in the metacognitive domain begins to make the case for strong claims of embodiment. Plausibly, certain subjects perform better than others in virtue of the fact that their increased interoceptive sensitivity provides them with increased sensitivity to noetic feelings, which generally serve as good guides to the overarching metacognitive process of determining knowledge, familiarity, confidence, etc.

But without further evidence it is unclear whether Chua and Bliss-Moreau's study shows causation rather than mere correlation, so that the crucial question becomes whether the correlations found by their study are indeed explained by a common mechanism. If correct, claims of embodiment will be justified, specifically claims about fluency being consciously accessible through the interoception of bodily afferents, suggesting an intricate brain-body interface in metacognition, possibly even a highly intricate one.

Let us now consider the second study conducted by Köhler's lab (Fiacconi et al., 2017). [9] Here, Fiacconi and colleagues sought to measure cardiovascular afferents that are normally consciously accessible, specially, those associated with heartrate acceleration, to determine whether the interoception of such afferents could potentially affect subjects' metacognitive judgments made on the basis of undergoing noetic feelings.

After measuring subjects' interoceptive sensitivity through a heartbeat detection task, Fiacconi et al. (2017) measured task-related cardiovascular changes while subjects performed facial recognition tests, reporting noetic feelings of knowing and associated degrees of arousal. Crucially, a positive relationship was observed between heartrate acceleration and the reported arousal of the noetic feeling, a relationship modulated by the subject's interoceptive sensitivity: "Together, these results suggest that relative heartbeat acceleration to old face cues is associated with stronger subjective feelings of knowing for old as compared to new face cues in individuals with high interoceptive sensitivity" (ibid, p. 75).

Thus, the degree to which subjects could accurately sense bodily afferents determined the degree to which heartrate acceleration correlated with the arousal of the noetic feeling. In other words, the more accurate subjects are at sensing bodily afferents, the more likely changes in heartrate acceleration will be representative of the arousal of the noetic feeling, such that greater/weaker heartrate acceleration will represent stronger/weaker arousal. This suggests, "to the extent that participants can 'tune into' visceral feedback, autonomic signals do indeed shape FOK judgments" (ibid, p. 77). Though,

Fiacconi and colleagues are not explicit about what it means to "shape" metacognitive judgments in this manner, some specifics can be inferred by combining the results of both studies.

Taken together Fiacconi et al. (2016) and (Fiacconi et al., 2017) suggest a strong embodied view, wherein bodily afferents do not merely draw attention to fluency signals, but make metacognitive information accessible in their own right, namely whether the stimulus is fluent (i.e., as observed by whether subjects report a noetic feeling of familiarity) and the degree to which the stimulus is fluent (i.e., the degree of arousal associated with the noetic feeling). The first study showed that the onset of noetic feelings correlates with the production of cardiovascular afferents, while the second study showed that the degree of arousal in noetic feelings is a function of both heartrate acceleration and the degree to which subjects can reliably interoceptively sense cardiovascular afferents. Together these results motivate adopting a neo-Jamesian theory about noetic feelings and a strong embodied view about metacognition, both of which will be defended below.

3.4 A neo-jamesian theory of noetic feelings

On the basis of Fiacconi et al. (2016), it can be inferred that noetic feelings can be produced, even erroneously (i.e., even for lures), if the presentation of stimuli is synchronized with the systolic phase of the cardiac cycle, wherein cardiovascular feedback is strongest. Crucially, this relationship *was not* observed if stimuli are presented during the diastolic phase of the cardiac cycle, wherein cardiovascular feedback is weakest.

Of course, Goldinger and Hansen (2005) found that subliminal buzzing could also produce noetic feelings, whose influence on behavior was counteracted when subjects were told about the buzzing's influence in advance, a result which Goldinger and Hansen believe showed that subjects can access a "genuine" (i.e., cerebrally-produced) signal to guide the unfolding thought process. That said, these results do not show that the genuine signal is solely cerebral. It only suggests there is a normative signal, one which subjects generally have access to, and it does not rule out the possibility that the normative signal is an embodied one, produced by a common mechanism between metacognition and interoception. Plausibly, as implied by Fiacconi et al. (2016), subjects might access a bodily signal crucially tied to the cardiovascular system that conveys information about processing fluency.

Consider again the results of Fiacconi et al. (2017) study. Here, an increase in heartrate acceleration was found to correlate with the onset of noetic feelings and, what is more, the degree of acceleration was found to correlate with the arousal of the feeling, a relationship moderated by

interoceptive sensitivity. Ultimately, the degree to which subjects are sensitive to bodily afferents determines the degree to which heartrate acceleration predicts the arousal of the noetic feeling: greater/weaker acceleration was found to correlate with greater/weaker arousal of the noetic feeling. This crucial finding points the way beyond mere correlation to the possibility of causation, since it suggests that the better you are at sensing bodily afferents, the more intense will be your noetic feelings, a relationship most easily explained by how those afferents *cause* such feelings.

That said, as previously discussed, Morris et al. (2008) observed similar patterns with SCRs, such that greater/weaker SCRs were found to correlate with greater/weaker arousal of noetic feelings, which was argued above not to evidence strong claims of embodiment because SCRs are not normally consciously accessible. But the crucial difference separating Fiacconi et al.'s two studies lies in how cardiovascular afferents are generally consciously accessible: we routinely feel our own heartbeat (from the inside), especially if heartrate is accelerating. Since Köhler's lab measured the relationship between, on the one hand, consciously accessible afferents and, on the other hand, the onset and intensity of noetic feelings during the production of such afferents, their results support a neo-Jamesian theory of noetic feelings.

Consequently, it is plausible that bodily afferents are causally responsible for making fluency signals salient, thus supporting for the case for embodiment, as bodily afferents serve as guides to the unfolding thought process. What is more, these results suggest cardiovascular afferents convey information about whether stimuli are fluently/disfluently processed, as well as the degree to which stimuli are fluently/disfluently processed, thus lending support to the case for strong embodiment, since subjects "tune into" their bodily afferents to discover metacognitive information.

As a result, these studies provide evidence in favor of Chua and Bliss-Moreau's proposal of a common mechanism shared by metacognition and interoception. Specifically, they share a common mechanism due to how the process by which noetic feelings fulfill their role in the cognitive economy (namely, that of guiding the unfolding of thought) is made possible through the interoception of bodily afferents, particularly those afferents produced by (or intricately tied to) cardiovascular activity.

One last question will need to be addressed before our discussion can conclude. Given what was discussed above about the intricate brain-body interface in metacognition, a proposal is needed for how bodily afferents convey information about metacognitive processing fluency. One proposal that strikes me as deeply plausible is that degrees of bodily arousal serve to index degrees of fluency, while bodily valence serves to index whether stimuli are fluently or disfluently processed (typically, but by no means necessarily, positive valence indexes fluency, while negative valence indexes disfluency). If this is correct, the function of the common mechanism

between metacognition and interoception is not unlike that of an interpreter, translating the language of the brain into that of the body, plausibly offering a high-fidelity rendition for subjects with healthy heart-brain relationships.

Finally, it is clear from our discussion that traditional theories of noetic feelings ought to be looked upon with skepticism, while embodied theories ought to pave the path forward. Traditional theories rely upon empirical claims that are likely false, since empirical evidence suggests that noetic feelings are not fundamentally distinct from other kinds of feelings: noetic feelings too depend upon extracerebral processes for their production, while also depending on the interoception of bodily afferents for the realization of their role within the cognitive economy. In other words, to echo Putnam's famous remark, noetic feelings *just ain't* (solely) *in the head*.

4. Conclusion and further research

The chief question investigated here was whether there are grounds for claiming metacognition is embodied in some crucial way. This question was answered in the affirmative as empirical evidence suggests that bodily afferents explain how information about metacognitive processing fluency is made consciously accessible to the subject in the form of noetic feelings, whose role in the cognitive economy is to enable and facilitate the unfolding thought process. In particular, the interoception of bodily afferents crucially tied to the cardiovascular system was suggested as making this role possible. The results discussed above suggest that traditional views of noetic feelings should be regarded with skepticism and a view that endorses a neo-Jamesian theory about noetic feelings ought to shape future investigation: when feeling a noetic feeling, you feel bodily changes (crucially tied to metacognitive changes).

One important direction of research opened up by the framework outlined above would seek to determine details surrounding the common mechanism shared by capacities for metacognition and interoception. This could potentially involve exploring the apparent relationship between noetic feelings, the cardiovascular system, and agency. Thayer and Lane's prominent neurovisceral integration model (NVM) conceptualizes changes in heartrate variability (HRV) as "an index of activity in a set of neural structures involved in physiologic, affective, and cognitive regulation" (Thayer & Lane, 2009, p. 86), whereby R. Smith et al. (2017) theorize that greater HRV underpins executive levels of control. Given what was discussed above about the link between noetic feelings and cardiovascular feedback, could changes in HRV predict processing fluency effects on behavior, and might these effects be modulated by interoceptive sensitivity? Might NVM have the tools to

describe the common mechanism between metacognition and interoception? Addressing these questions will shed light on the proposed common mechanism.

Second, research could be done on the embodied nature of other noetic feelings. For example, what is the relationship between interoceptive sensitivity and *episodic* noetic feelings, e.g., the feeling of mental time travel? Could these feelings have their own unique bodily basis? Third, while our discussion focused on the feeling of knowing, there are other semantic noetic feelings, such as the feeling of forgetting, each with a distinct phenomenal character. How might these phenomenal differences be accounted for?

Finally, there are several deeply profound questions. Why does the cardiovascular system play a role in enabling and facilitating advanced cognitive capacities by making noetic feelings conscious, capacities for discrimination, identification, and recollection? Is this mechanism online at birth or does it develop throughout childhood, e.g., as social cognition develops? Might there be evidence of a similar brain-body mechanism in other animals? And if so, does this mean that these animals experience noetic feelings? Do noetic feelings, qua feelings, play an important role in the phylogenetic origin of distinctly human capacities for acquiring self-knowledge, such as the more sophisticated metacognitive, mentalizing/metarepresentational, capacities? To address these issues properly, much philosophical and empirical work will need to be done.

Notes

1. The term "metacognitive" is often deployed in two distinct ways (e.g., Shea et al., 2014). On the one hand, it is used to refer to metarepresentational processes and their products, in which representations are represented *explicitly*, such as when mentalizing, wherein subjects represent beliefs as beliefs (i.e., entertain second-order mental states). On the other hand, processes and their products are also described as metacognitive when they inform subjects *implicitly* about cognitive processes. It is exclusively in this latter sense (i.e., implicit metacognition) that noetic feelings are assumed here to be metacognitive.
2. Or as Tulving would describe it, noetic feelings carry information about entities that enable "symbolic [and semantic] knowledge of the world", which allows "the organism to be aware of, and to cognitively operate on, objects and events, and relations among objects and events, in the absence of these objects and events" (ibid, p. 3).
3. While it is true that the Reder et al.'s model is largely about computation, it also has crucial implementational commitments since it describes exclusively *mnemonic* nodes. Thus, the computational infrastructure responsible for producing noetic feelings cannot be implemented in an embodied way, since this would amount to the counterintuitive claim that semantic memory is realized by non-neuronal, extracerebral cell populations.

4. It might be useful to point out that the traditional view is likely the consequence of its historical debt to cybernetic theories of metacognitive control structures (Conant & Ashby, 1970; Flavell, 1979; Nelson & Narens, 1990), wherein noetic feelings are conceived of as feedback signals generated by cognitive comparators (see Proust (2013) for an extensive discussion). But by no means is this view a thing of the past. This cybernetic story has been significantly updated in light of the Bayesian brain hypothesis (Knill & Pouget, 2004) and predictive coding architectures (Friston & Kiebel, 2009) to describe noetic feelings as subjectively accessible scalar representations that approximate the precision of the underlying Bayesian distribution (its inverse variance), which, in turn, is theorized to be a representation of the activity in neuronal populations (see, e.g., Meyniel et al., 2015).
5. For example, Nussinson and Koriat (2008) distinguish between cognitive feelings (e.g., feelings of fluency and feelings of knowing), bodily feelings (e.g., feelings of physical intensity), and affective feelings (e.g., feelings of pride).
6. While Alter and Oppenheimer cite embodied cognition as one of the "instantiations" of fluency, embodied information (such as that produced by the activation of the corrugator muscle) is also described as *on par with* phonological, lexical, syntactic, and mnemonic information, each theorized to involve an *independent process* for the production of feelings of fluency.
7. My thanks to an anonymous reviewer for insisting I think of better and better analogies to articulate the difference between the weak and the strong views. This final formulation helped me to think more clearly about my own stance on the embodied nature of noetic feelings.
8. One reason for my appeal to an intricate brain-body interface, wherein metacognitive information can be thought of as translated into bodily valence and arousal, is to sidestep debates about embodiment that center around the need for constitution over mere causation (see e.g., Adams & Aizawa, 2008). The term "constitution" can be used to describe many distinct relations, from the nomologically or metaphysically necessary to part-whole relations, all of which, if pursued, would require a commitment to certain brain-body metaphysics that are not particularly illuminating for the present case. By talking about the intricateness of the interface, I aim to talk about the importance of embodiment in a manner that relaxes the need to address some of these metaphysical concerns. Thus, I am happy to concede that the body plays (only) a causal role in metacognition, but, I argue, its causal role is so important that an exhaustive account of how metacognitive processes unfold might be lost if this role were neglected. This could be called a "constitutive relation" if by "constitutive" it was meant "explanatorily prudent".
9. To clarify, this second study, Fiacconi et al. (2017), investigated the relationship between FOK ratings and heartrate acceleration as a function of interoceptive sensitivity during a facial recognitive task, which is distinct but crucially related to Fiacconi et al. (2016), discussed above (Section 3.2), that presented face cues on or off heartbeat (systole or diastole) during a facial recognition task and probed whether this correlated with the onset of noetic feelings.

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