TIME, UNITY, AND CONSCIOUS EXPERIENCE

by

MICHAŁ W. KLINCEWICZ

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Jesse Prinz:

________________ ____

Date Chair of Examining Committee

Iakovos Vasiliou:

________________ ____

Date Executive Officer

Supervisory Committee:
David M. Rosenthal
Tony Ro
Barbara Montero
Pete Mandik

THE CITY UNIVERSITY OF NEW YORK

ABSTRACT

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Michał W. Klincewicz

Adviser: Professor David M. Rosenthal

In my dissertation I critically survey existing theories of time consciousness, and draw on recent work in neuroscience and philosophy to develop an original theory. My view depends on a novel account of temporal perception based on the notion of temporal qualities, which are mental properties that are instantiated whenever we detect change in the environment. When we become aware of these temporal qualities in an appropriate way, our conscious experience will feature the distinct temporal phenomenology that is associated with the passing of time. The temporal qualities model of perception makes two predictions about the mechanisms of time perception; one that time perception is modality specific and the other that it can occur without awareness. My argument for this view partially depends on a number of psychophysical experiments that I designed and implemented myself and which investigate subjective time distortions caused by looming visual stimuli. These results show that the mechanisms of conscious experience of time are distinct from the mechanisms of time perception, as my theory of temporal qualities predicts.

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Dla Ignacego i Ewy Łukasiewiczów

But the notes themselves have vanished before these sensations have developed sufficiently to escape submersion under those which the following, or even simultaneous notes have already begun to awaken in us. And this indefinite perception would continue to smother in its molten liquidity the motifs which now and then emerge, barely discernible, to plunge again and disappear and drown; recognised only by the particular kind of pleasure which they instil, impossible to describe, to recollect, to name; ineffable;—if our memory, like a labourer who toils at the laying down of firm foundations beneath the tumult of the waves, did not, by fashioning for us facsimiles of those fugitive phrases, enable us to compare and to contrast them with those that follow.

—Marcel Proust, In Search of Lost Time

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1.1 What is the Unity of Consciousness?

Conscious experiences appear to be unified into a stream. This appearance informs a commonly held view about the nature of consciousness. On this view, individual conscious experiences form a seamless, interconnected whole, which is sometimes also thought to be constitutive of the subject that has those very experiences.

Fortunately, this picture dominates literary masterpieces, such as Marcel Proust's In Search of Lost Time or James Joyce's Ulysses. Unfortunately, it also informs theorizing about consciousness. The metaphor of a stream is misleading when it comes to understanding the psychological mechanisms that underlie conscious experience.

It is perhaps not surprising that the stream metaphor dominates our thinking about conscious experience and has had an influence on theories of consciousness. Typically, people report having what can best be described as a stream of conscious experiences. They do not report having breaks or seams in their consciousness unless they are in extraordinary circumstances or under the influence of drugs.

Take, for example, the conscious experiences one might have at night, while standing across the river from Manhattan. The scene includes a number of distinct buildings, most of which have distinct windows, some of which might be illuminated. There might also be some whirring helicopters nearby, and an occasional breeze carrying odors of the river.

Despite all this complexity, the visual scene, the sounds, and the smells are, in an obvious sense, a single experience of Manhattan from across the river. This holds true at a single time and also for a succession of conscious experiences over time. The conscious appearance of the Manhattan skyline is unified, so it seems almost inevitable that the experiences that underlie it are themselves unified. And so we slide into the stream view.

But if we step back from the phenomenological platitudes, questions arise immediately. First, what unifies our conscious experiences into a stream—a sort of phenomenological glue? Secondly, why are conscious experiences unified?

One easy answer to both of these questions involves the subject or some related notion, such as the self or person. On this view, conscious experiences are unified in virtue of a single enduring subject having them. The structure of consciousness parallels this unified structure of the subject.

If it is the unified subject that unifies our conscious experiences into a stream, we also have an answer to why our conscious experiences are unified. Without that unity, the subject would itself be fragmented, which conflicts with how we typically conceive of ourselves. We typically conceive of ourselves as unified entities that endure through time. And so, without further reflection, we might arrive at a vindication of the stream view of consciousness, according to which conscious experiences are unified.

In the philosophical literature, this notion of unity of consciousness has been described as "subsumptive" unity (Bayne and Chalmers 2003, p. 26-7) and also as "phenomenal" unity (Bayne 2010, p. 10-1). When conscious experiences are phenomenally unified, they are unified in: "a single encompassing state of consciousness that subsumes all of my experiences: perceptual, bodily, emotional, cognitive, and any others" (Bayne and Chalmers 2003, p. 27). Importantly, this notion is distinct from other unities of consciousness (Bayne 2010, p. 11-14).

First, phenomenal unity is not the unity that concerns the binding problem, that is, the problem that our perceptual system faces in integrating disparate features of a perceived object and different sensory modalities. Presumably, the binding problem is not, strictly speaking, a problem of consciousness, but a problem of perception. Perception can, but need not involve consciousness.

Phenomenal unity should also be distinguished from the unity that accompanies conscious experiences of multiple objects, which are presented as existing in a single unified space. Explaining this unity involves specifying the various psychological processes that result in conscious experiences of a unified world or its features. While this notion of unity is closely related to the unity of consciousness at stake, it does not capture the uniquely phenomenological notion. We can represent the world as unified without having a unified experience.

Finally, phenomenal unity is not the same as the unity of a single subject, but it is importantly related, at least in the work of Bayne and Chalmers. The unity of the subject is satisfied trivially if we accept that "if a set of experiences of a subject at a time is subject unified, then that set is unified" (Bayne and Chalmers 2003, p. 26). So, on their view, any set of conscious experience one has at a given time are phenomenally unified because a single subject has them.

Presumably, unity of the subject extends to conscious experiences over time, as well as to the conscious experiences at a given time. Together with the presumed trivial inference from subject unity to phenomenal unity, if successive conscious experiences are subject unified they are also phenomenally unified. The result is a version of the stream view of consciousness, on which conscious experiences are seamlessly connected and also closely connected to the subject.

Bayne and Chalmers seem to accept the conditional that leads to this conclusion as relatively trivial. I am skeptical of it. My main reason for this is that the claim that subjective unity implies phenomenal unity is tenable only if we assume that all the experiences a single subject *has* are conscious.

But that is clearly not the case. Unconscious mental states are still plausibly *had* by a subject—they belong to someone. For example, my hearing someone using my name at a cocktail party is still *my* hearing it, even though I am not explicitly aware of hearing it at the time it occurs. So at least for that reason it cannot be the case that if a set of mental states is subject unified it will be phenomenally unified: some subject unified mental states are going to be unconscious, and hence not carry with them any appearance of phenomenal unity.

The triviality claim can be challenged in another way. It is not obvious that conscious experiences always involve the subject. David Hume, for one, observes that:

> There are some philosophers, who imagine we are every moment intimately conscious of what we call our SELF: that we feel its existence and its continuance in existence; and are certain, beyond the evidence of a demonstration, both of its perfect identity and simplicity (Hume 2000/1739,

1.4.6.1).

The philosophers Hume is referring to in this passage claim that the SELF is always present in conscious experience, as the triviality claim seems to assume.

But, famously, when Hume attempts to confirm this view by introspecting, he fails:

> For my part, when I enter most intimately into what I call myself, I always stumble on some particular perception or other, of heat or cold, light or shade, love or hatred, pain or pleasure. I never can catch myself at any time without a perception, and never can observe any thing but the perception (Hume 2000/1739, 1.4.6.3).

As a result, Hume is skeptical of the view that the SELF is presented in conscious experiences. For whatever such introspective exercises are worth, I think we should follow Hume, since we will find no SELF when we introspect, either.

Following this observation, Hume urges that "we must distinguish betwixt personal identity, as it regards our thought or imagination, and as it regards our passions or the concern we take in ourselves" (Hume 2000/1739, 1.4.6.15). Personal identity as it regards our passions and concern we take in ourselves is the unity of us as selves, while personal identity as regards our thought or imagination is matter of the unity of successive conscious experiences.

Hume's suggestion is to split the problem of unity of consciousness into two distinct problems. The first is the problem of what unifies us as subjects. And the second is the problem of what unifies conscious experiences at and over time, if thre is anything that unifies them at all.

Hume had a view about what a SELF is (a bundle of ideas) as well as a view about what constitutes the unity of conscious experiences (relations of resemblance and causation). Whatever we make of these views, Hume distinction makes it obvious that we cannot take it as trivial that subject unity implies phenomenal unity, as Bayne and Chalmers seem to assume. It could turn out that there is no subject that unifies our experiences at all.

Given all of this, we have at least two reasons to think that subject unity might be a wider notion than phenomenal unity. First, unconscious mental states are still had by someone. Secondly, it is not obvious that conscious experiences involve a distinct entity such as a subject (or self) at all.

In that spirit, I presume that Hume would find the view that I offer in the course of this dissertation congenial, at least in that one respect. The phenomenal unity of consciousness should be disentangled from the sense that conscious experiences always involve a subject (or self). Conscious experience of unity at and over time just is the sense of unity that Hume identified as pertaining to "thought or imagination."

That does not mean that the characterization of the unity of conscious I offer has no room for the sense that our self is involved in conscious experiences. Such a sense is a platitude that can comfortably fit within the framework I propose as long as it does not play the role of also explaining the sense that conscious experiences are themselves unified.

After stating what notion of unity of consciousness I am concerned with, my aim is to state a theory that comports with the conscious appearance of such unity without also implying a unity in the experiences that underlie it. Also, please note the narrative of this dissertation is by no means straightforward. The argument for my view is presented in a non-standard way and I address the relevant issues from several angles. These include a survey of the Phenomenological tradition, and a good amount of empirical psychology and neuroscience.

I take this approach to be promising mostly because of the difficulty I encountered in characterizing the unity of consciousness in a relatively theory-neutral way. Traditionally, the unity of consciousness has been characterized in terms of a theory of something else, such as a theory of consciousness or a theory of the self. My non-standard approach is an attempt to side-step those entanglements in the interest of a better final product.

1.2 Experiential Atomism and the Unity of Consciousness

For a variety of reasons, it is useful to think of mental activity as involving mental states, such as thoughts, sensations, and so on. One good reason to do this is that the talk of mental states makes it possible for us characterize and predict the behavior of others. Thoughts, for example, have intentional content and assertoric attitude. Given that, when someone tells us that they think *p*, thus expressing their thoughts that p, we have a good prima facie reason to think that they will behave accordingly.

Mental states are characterized as distinct entities, with distinct representational properties, such as content, mental qualities, and attitude. This is also true for conscious mental states. So, if we think of conscious experiences as conscious thoughts, conscious sensations, and so on, we seem to end up with a particular conception of consciousness, namely, with one that characterizes individual conscious experiences as distinct from one another.

On the resulting view, each conscious experience is independent from other conscious experiences—a distinct snapshot, with a particular set of properties that individuate it from other snapshots. This conception jars with the phenomenology of unity, which underlies the stream view I outlined above. Conscious experiences appear to not be distinct atomic snapshots, but a unified stream.

This is what I take to be the crux of the phenomenological challenge to an atomist conception of consciousness, which is articulated by Sydney Shoemaker, among others (Shoemaker 2003). An extensive discussion of Shoemaker's argument and consciousness holism is taken up in Chapter 2, so now I present only a brief sketch of the challenge. Roughly, Shoemaker argues that atomism suggests that conscious experiences are snapshots, while phenomenology suggests the opposite.

Importantly, this phenomenological challenge can be parsed into two closely related sub-challenges. The first sub-challenge concerns the unity of consciousness at one time. An atomist view, which urges that conscious experiences are distinct from each other at any given time, seems to contradict this manifest unity.

The second sub-challenge concerns the unity of consciousness over time and the seamless continuity apparent in conscious experience from one moment to the next. The atomist view appears to imply that conscious experiences are disconnected from moment to moment, so it seems to imply a phenomenology of disconnected snapshots. This is incompatible with the apparent phenomenology of a stream.

The phenomenological challenge to atomist theories of consciousness is not fatal. The typical strategy here is to explain the appearance of unity as an illusion (Clark 2002; Blackmore 2002; Dennett 1991; O'Regan 1998, 1992; Tye 2009, p. 155-82). On these views, the appearance of unity is the result of a version of the refrigerator light illusion.

Daniel Dennett’s account is paradigmatic so I will rehearse it here. When we first look at a wallpaper pattern of identical Marilyn Monroe portraits, Dennett argues, it is highly unlikely that our brain copies and pastes a single picture of Marilyn Monroe all over our phenomenal field. We simply do not have the resources to accomplish this task at first glance at the wall.

The more plausible way to understand what happens, the inference goes, is that we see some small part of it in our fovea and then our brain “jumps to the conclusion that the rest are Marilyns, and labels the whole region ‘more Marilyns’ without any further rendering of Marilyn at all” (Dennett 1991, p. 355). Unless the brain receives information to the contrary, it generalizes and makes our perceptual system ignore the rest of the wall.

Of course, it does not seem that way to us. Our phenomenology presents a plenum that contains a field of identical Marilyn portraits, all unified in one visual field. However, we assume that there is more phenomenology available, even though it is not there at all, in any sense. Whatever our brain labels as ‘more Marilyns’ does not make it into our consciousness at all.

So, just as with the refrigerator light illusion, without an independent reason to think that the light goes off when the door is closed, a naïve person might (or perhaps should) assume that the light is on all the time. We assume that conscious experiences are "on," because whenever we are aware of them they appear that way.

The example of a wall of Marilyns can be also used to explain the appearance of unity of consciousness over time. Just as with conscious experience at one time appearing to be a plenum, conscious experiences over time appear to be an uninterrupted stream, all in virtue of the way that they are represented in awareness. We assume consciousness is "on" during the temporal gaps between conscious experiences.

The refrigerator light argument suggests that it is simply wrong to think that atomism cannot account for the stream-like continuity of conscious experience. But there is a remaining problem—the refrigerator light story is not enough. This is the sense of the passing of time or, as it is sometimes called, the problem of temporality of conscious experience (Noë, Pessoa, and Thompson 2000; Kelly 2005). To complete an account of the phenomenology of a stream, an atomist theory should also give an account of temporality.

Typical examples of the experience of the passing of time involve a melody, so I will follow suit here. When we consciously hear successive notes A, B, C, each of those experiences presents us with a distinct auditory quality of A*, B*, and C*.[1] And when the C note sounds at the end of the A-B-C phrase, we have a distinct kind of experience from the one in which we only hear the C. The final note is presented in our conscious experience as itself, that is, as a C, but also as a part of a phrase A-B-C.

[1] To make things easier, I am using a star to designate a mental quality as opposed to a perceptible property. So, a P* is in my mind while P is out in the world.

The reason why we can experience a melody as a melody is because it appears to have temporal extension (Phillips 2010, p. 178). If it did not appear that way, then only the contents of the present conscious experiences would appear to us and we would miss out on what makes listening to music worthwhile. We would never be able to consciously experience, among other things, the distinct quality of a flute C following a flute A and a flute B.

Conscious perceptual experience of that simple melody at any given moment will involve the mental qualities of the individual notes. However, the temporal aspect of conscious experience allows the notes that passed to contribute, somehow, to the experience of the melody as such. How this can be the case, meaning, how we can experience temporal extension, on a snapshot conception of conscious experience, is the remaining problem for an atomist account of the appearance of unity of consciousness. This dissertation offers an account of the unity of consciousness over time that can answer this and other related questions.

Below I outline the narrative and the chapters of this dissertation, which eventually lead to a statement of such a theory. In the interest of clarity I will repeat some of what I have said above where necessary. In section 6 I highlight some out some of the relationships that my view has to broader philosophical problems.

2. Chapter 2: Unity of Consciousness over Time

Chapter 2 is a survey of philosophical theories of temporality. Ultimately, I find the these theories wanting for a variety of reasons, even though some of them are compatible with the claim that a succession of conscious experiences is itself seamless and continuous, as our phenomenology suggests. The ultimate goal of this chapter is to point the way towards an answer to the second phenomenological sub-challenge to atomism without the problems facing those views.

The main difficulty that faces all accounts of the conscious experience of the passage of time is to reconcile the view that conscious experiences are individual entities and the continuous and seamless we ordinarily experience. This difficulty parallels the difficulty facing an atomist theory of consciousness, so, given this connection, I treat the second sub-challenge to atomism and the problems associated with giving a theory of passage in the same way.

What both problems share is the explenandum, which is a particular characterization of the unity of consciousness over time. Our consciousness appears unified because any particular conscious experience seems to flow from the conscious experience that preceded it and into a conscious experience that succeeds it. Given this temporal flow, a succession of conscious experiences appears to be a stream.

Unfortunately, this characterization of the phenomenology of unity over time generates a puzzle. On the one hand, past conscious experiences and possibly also anticipated conscious experiences contribute, in some way, to the contents of conscious experience in the present. On the other hand, the present does not appear to include past conscious experiences.

None of the accounts I survey in Chapter 2 provides an entirely satisfactory answer to how this can be the case. Theories of temporality advanced by Immanuel Kant and David Hume can yield a solution to the puzzle. However, they do this by relying on problematic psychological assumptions about memory and inference, which are hard to square with what we know about the mind today.

Theories given by William James, Edmund Husserl, and Franz Brentano, on the other hand, are committed to a problematic claim about the relationship between the content of conscious experience and the properties of underlying mental states. On these views, the temporal ordering of mental states corresponds to the temporal succession of conscious experiences, which is a claim that is both empirically and theoretically problematic.

For one, such a conception of conscious experience over time makes it impossible to account for a range of temporal illusions, such as the phi phenomenon or the cutanous rabbit (Dennett and Kinsbourne 1992). Temporal illusions strongly suggest that the temporal order in which conscious experiences occur does not have to correspond to the temporal order present to us in our phenomenology. For example, a conscious sensation of a red dot that occurs at time *t* can present that dot as occurring at *t* plus or minus a few hundred milliseconds or so. So the timing we are presented in experience is to some extent independent of the timing of the underlying mental states.

I conclude that while James' and Brentano's theories can solve the phenomenological puzzle of the experience of the passage of time, they do so at too great a price. A commitment to a close connection between the timing presented in conscious experience and the timing of underlying mental states is untenable. Because of this, I argue that we should reject them.

Husserl's theory, on the other hand, is problematic for a different reason. The conceptual machinery that Husserl presents as the solution to the problem of temporality does little more than name the features of conscious experience to be explained. Husserl names the problem instead of solving it.

Bergson's account of passage seems to solve the puzzle without problematic commitments to the temporal ordering of conscious experiences. He also does not merely name the problem, as Husserl seems to. The problem with Bergson's view is that it depends on the immateriality of the mind, which is a highly contentious and, arguably, indefensible claim. Given this commitment, it is not clear that Bergson's theory can address the problem of temporality in a way that is relevant to the project of understanding the mind from the perspective of contemporary cognitive sciences.

I conclude Chapter 2 with the claim that we should reject all the theories I discuss, especially in light of a viable alternative in the representationalist strategy put forth by Dennett and Kinsbourne. On this representationalist view, consciously experienced timing of an event is determined by how it is represented and not by the timing of the occurrence of the mental states that underlie that experience. Given this, representationalist theories have no problem accounting for temporal illusions

Overall, Chapter 2 constitutes a polemic aimed at a series of theories of the experience of succession. The conclusion of that chapter suggests that an alternative, which avoids the difficulties associated with those theories, can provide a solution to the original phenomenological sub-challenge of the unity of consciousness over time. However, as such, Chapter 2 does not offer such a solution but only point to its possibility.

It turns out that at least one version of atomism—one based on representation—is compatible with the phenomenology of unity and the initial phenomenological challenge can be met, contrary to what Shoemaker and others have suggested. But pointing to representation only goes so far. The task of giving a full theory of temporality from within this framework takes up the remainder of the present work. The view I present in Chapters 3, 4 and 5 is explains what underlies the appearance of unity of consciousness over time and gives an account of conscious experience of the passage of time.

3. Chapter 3: Temporal Mental Qualities

The positive view of what underlies the phenomenology of the unity of consciousness over time consists of two theories. The first is a theory of temporal perception, which I offer in Chapter 3. The second is a theory of conscious experience of time, which I offer in Chapter 5.

The model of temporal perception I offer Chapter 3 is derived from the Quality Space Theory (QST), also known as Homomorphism theory, which sits among a family of functionalist accounts of mental qualities (Sellars 1956; Rosenthal 2005; Meehan 2002; Shoemaker 1975; Clark 1993). According to QST, mental qualities are related to each other in ways that reflect the relations between perceptible properties and form families that can be characterized as spaces of relations. My model extends this to the temporal domain of perception.

QST takes advantage of the similarities and differences between mental qualities. These similarities and differences form distance metrics that reflect the number of discriminations an organism can make between any two perceptible properties. And the metrics can define spaces of relations that reflect similar spaces of perceptible properties.

For example, mental red is more similar to mental orange than to mental blue. An organism that can discern these differences can instantiate sensations with those mental qualities. The metrics between individually discriminable mental qualities define spaces of relations among the mental qualities that correspond to families of perceptible properties.

The work in Chapter 3 extends QST to the temporal dimensions of perception and characterizes the unique features of the temporal quality space. The secondary goal of this chapter is to square the temporal quality space model with what we already know about temporal perception. It turns out that there is much empirical evidence that can be used to support it.

The theory of temporal mental qualities I propose has several potentially controversial features. First, it allows for perception of time without awareness. Secondly, it implies that each sensory modality has its own proprietary representational properties for timing and duration.

Given these difficulties, Chapter 3 has a non-standard structure. A major part of it consists of an empirical argument in support of the aforementioned features of temporal perception. I first lay out the empirical claims, and then proceed to fit my theory to them.

Psychophysical and neuroimaging studies of temporal perception strongly suggest that time is processed individually by each modality and that it can occur unconsciously. Also, a portion of that literature is concerned with various temporal illusions, which suggests that they are a normal feature of temporal perception. Finally, it is almost universally accepted by researchers in those fields that information about time can be processed and represented unconsciously.

The fact that the temporal quality space model is compatible with all of these empirical findings is a distinct advantage of the view. In addition, the theory laid out in Chapters 3 illustrates how all of the empirical results hang together. Temporal mental qualities can be identified through their role in the mental economy of an organism. They are not, however, to be identified through the ways that they appear to be in conscious experience.

Given all this, the temporal quality space model has some advantages. However, it is not a complete account of mental time. To have a complete account of mental time, we also need to explain the temporal aspect of conscious experience, and this is the focus of Chapter 5.

However, before we get there, I come back to the claim that perception of time can occur without awareness. In Chapter 4, I address this claim by reporting on an experiment that I carried out in Dr. Tony Ro's Neuroscience Lab in City College of New York designed to weigh in on the issue of unconscious time perception.

4. Chapter 4: Unconscious Perception of Time

In this Chapter I present further evidence that supports the temporal quality space model. In particular, I focus on the prediction that perception of time can occur independently of awareness. The evidence I present consists of both a literature review and a report on psychophysical experiments that I carried out myself. In the appendix I include a section of the algorithm that I implemented for those experiments.

The main goal of the literature review in Chapter 4 is to give appropriate context to the experiments themselves. I review some of the existing neurobiological models of time perception and some of the methodologies used in their support. This methodology depends heavily on eliciting subjective reports from participants and then making inferences about the neural mechanisms that underlie them. The temporal quality space model presented in Chapter 3—if vindicated—would put in question these results.

The standard methodological assumption made in time perception research is that subjective reports and discriminations are caused by the same mechanism. The temporal quality space model proposes that subjective verbal reports are connected to the mechanisms of awareness. Discriminations, on the other hand, are connected to the mechanisms of perception that are independent of awareness.

There is some evidence in the literature on time perception for a distinction between the mechanisms of time perception and conscious experience of time. However, this evidence is scant and indirect. None of the studies reviewed in Chapter 4 address that issue directly. The results themselves, when rightly interpreted, point to that conclusion.

The experiments that I carried out aim to improve on that situation and give direct evidence for a functional distinction between the mechanisms of time perception and conscious experience of time. These experiments also serve as pilots for future work that would address the question of neural mechanisms involved. That work is, however, outside the scope of this dissertation. The main goal here is to make a case for the temporal quality space view and thereby give the required theoretical scaffolding for a theory of the conscious experience of time.

5. Chapter 5: Conscious Experience of Time

The discussion in Chapter 5 is a continuation of the discussion of temporal mental qualities from Chapters 3 and 4. The theory of consciousness that I take to be most compatible with all the features of the temporal quality space model is the higher-order thought theory of consciousness (Rosenthal 2005). Temporal quality space model accounts for the role that temporal mental qualities play in the discernment of perceptible temporal properties. Higher-order thought theory, on the other hand, accounts for conscious appearance that might accompany those discriminations.

It is important to note, however, that the temporal quality model does not depend on the higher-order thought theory. Arguably, the temporal quality model can be neutral about the mechanisms of consciousness. Any theory of consciousness that makes a psychologically viable distinction between conscious and unconscious mental states will be compatible with the temporal quality model of perception that I offer in Chapter 3.

According to the higher-order thought theory, conscious experience is the result of a typically unconscious thought about a mental state that one has at that moment. On this view, the qualitative character of conscious experience is completely determined by the content higher-order thought. However, any theory of consciousness which explains the qualitative character of conscious experience in terms of awareness—whether that awareness is implemented by thoughts, sensations, higher-order content or whatever—can make use of the account of the experience of the passing of time offered here.

Take, for example, a visual sensation of red. According to the quality space model, such a sensation instantiates a red* mental quality. This quality enables the sensation to play its role in the organism's discernment of red in the environment. Red* can do this because it bears a set of relations to other mental qualities such as orange* and blue*, which reflects a set of relations between red, orange, and blue properties in the environment.

If a sensation of red is conscious, that is because one is aware of that sensation as a sensation of red. And the way that that awareness characterizes the sensation will determine the qualitative character of the experience. Now put this together with quality space theory and we have an account of conscious qualitative experience.

If one's awareness characterizes the sensation of red as occupying the place of red* in the quality space of colors, the result is a conscious sensation of red. But if one's awareness characterizes the sensation is some other way, perhaps as being blue*, the result is a conscious sensation of blue. This means that the mental quality instantiated by the sensation and qualitative character presented in conscious experience do not have to match.

One's awareness accounts for the temporal aspect of conscious experience in a similar way. A sensation that instantiates a temporal mental quality need not be conscious. But when it is, it is in virtue of one's awareness, which characterizes it with respect to the relative location of that quality in a temporal quality space.

The temporal aspect of conscious experience includes timing, duration, and succession. Conscious experience of timing represents the onset and offset of a more basic mental quality, such as color or sound. And the conscious experience of duration represents both an onset and offset as flanking a more basic mental quality.

However, conscious experiences of timing and duration might seem not to be sufficient to result in a conscious experience of succession. A person that experiences the onset and offset of red square and its duration does not thereby also have to have a conscious experience of the succession of conscious experiences of the red square. Duration and timing might be presented in one's phenomenology, but be presented in disjointed snapshots of the red square, as is presumably the case for people with motion blindness (Zeki 1991).

Each successive moment that such a person experiences the red square would be qualitatively similar to the next, except that each would present a different experience of duration. The qualitative character of succession that we normally experience when looking at something for some time would appear to be absent in their case. But is that really true?

A normal person's conscious experiences occur in quick succession to one another. We know, for example, the rate at which we perceive disconnected stills of a movie as moving—approximately 30 Hz or 30 frames per second. Bring that rate down to 20 Hz, say, and the movie will start to look jerky.

Presumably, a similar thing might occur in conscious experience. When instances of our awareness occurs at, say, 30 Hz or faster, we experience smooth succession and temporality, and when they occur at a rate of less than 30 Hz, the stream of our conscious experiences starts to appear like a sequence of stills. In this case, just as in a movie reel that is slowed down, we would lose the sense of continuity that accompanies our conscious experiences.

On this view, the person that happens to have no experience of succession might become aware of their mental states at a slower rate. The result would be, presumably, a disjoint and jarring phenomenology, just as is the case when someone turns off the movie projector and we start to see the individual frames of the reel. Nonetheless, the rate of occurrence of awareness is not enough to produce the appearance of unity of over time. We must also have a sense of the passing of time.

Or at least this is one way of understanding where the experience of continuity comes from on an atomist conception of consciousness. However, this strategy does not actually answer the crux of the problem of the experience of succession. It does not explain where the sense of the passing of time actually comes from, that is, it does not explain why conscious experiences occurring at a 30 Hz rate appear to be happening in time.

And it does not do much to answer the second phenomenological sub-challenge to atomism, nor does it resolve the puzzle that concerns the theories discussed in Chapter 2. The assumption there is that the most problematic thing about the experience of the passing of time is that it involves two distinct phenomenological features that are seemingly incompatible. On the one hand, conscious experiences appear imbued with the content of past experiences, as is the case when we listen to a note being played continuously for 5 seconds. On the other hand, past conscious experiences do not linger in a way that afterimages or echoes might.

For example, consciously experiencing 5 second melody being played on a flute is qualitatively different from listening to the tones that compose it in mere succession. Each tone we consciously experience informs, in some way, our conscious experience of the tone that succeeds. Without this phenomenological feature, we could probably not experience the tones as fitting naturally with the melody or as jarring with it. The problem of the experience of succession, then, is that even though the past sounds in some way inform the quality of the present conscious experience, we do not hear a chord. The 30 Hz account does not address this issue.

However, the complete theory of temporality I offer in Chapter 5 does. It can resolve the tension between these two seemingly incompatible features of the experience of passing of time. In short, past conscious experiences do not appear to linger in the present because we are aware of the relations to those experiences, not the experiences themselves.

On this view, each successive conscious experience is distinct from the other, thus preserving atomism. However, the sense that past conscious experiences inform present ones is preserved. Temporal qualities inform the present with the past are the via the relations that hold between them.

Let us say the flute starts a melody at t1 and ends at t2 and plays the same C note throughout this time. According to the temporal quality space model our awareness at t2, when the C is last sounded, characterizes the duration* quality of that sensation differently from the way that our awareness characterized it at t1. This is because that quality bears a distinct set of relations to the onset of the C at t1 and we are aware of it as such.

So even though the auditory mental quality characterized by our awareness is the same, that is, a C, the role that it plays in determining the duration* mental quality is different from moment to moment. This difference makes itself manifest in our conscious experience through our awareness of the relations that those qualities bear to one another. The result is a qualitative *temporal* difference from moment to moment without a qualitative *auditory* difference.

On this view, the mental qualities instantiated by the past sensations are responsible for the way that duration will be represented in the sensations that follow. If the flute continues sounding the C for 5 seconds, each successive sensation of the C will represent its duration as longer. And, according to the view on offer, the awareness in virtue of which we are conscious of auditory sensations of a flute characterizes them with respect to their location in the temporal quality space.

And so goes the explanation of the experience of temporal extension on the temporal quality space view I outlined above. The passing of time does not reflect any special mental quality of succession or temporal extension and it does not appeal to a connection between individual conscious experiences. It is merely a product of the relational nature of temporal mental qualities.

6.1 Features of the View: Whither Unity of Consciousness?

On the view I offer, conscious appearance is a matter of the way that our awareness characterizes individual mental states. It appears to us that experiences are continuous and temporally extended, because that is how our awareness of them characterizes them. On this view, appearance of unity might, but does not have to correspond to reality.

So is the unified phenomenology that underpins the commonly held stream view an illusion that hides a fragmented reality? According to atomism, it is. Conscious mental states are distinct from each other, and the phenomenology that they underlie hides this fact.

On the view I offer, our awareness characterizes mental states as unified, clumping them together in our phenomenology by the relations that obtain between individual temporal qualities. However, the mental states themselves, as well as our awareness of them are disjoint. Consequently, the unified phenomenology of consciousness does not reflect the fragmented mental reality that underlies it.

This rather dim view of the unity of consciousness is not without precedent. Famously, Dennett has argued that consciousness is fundamentally fragmented, and the appearance of unity is the result of us not being aware of the gaps. It is computationally impossible, Dennett argues, that when we first look at the wall, our brain copies and pastes a single picture of Marilyn Monroe all over our phenomenal field.

Instead, Dennett urges, we focus on one part of the wall and our brain "jumps to the conclusion that the rest are Marilyns, and labels the whole region 'more Marilyns' without any further rendering of Marilyn at all" (Dennett 1991, p. 355). Unless the brain receives information to the contrary, it will generalize and make our perceptual system ignore the rest of the wall.

Of course, it does not seem that way to us. Our phenomenology seems to us to be a plenum of identical Marilyn portraits, all unified into one. But, Dennett argues, that is because whatever we aware of at any given moment exhausts our phenomenology—we assume that there is more phenomenology available, even though it is not there at all, in any sense. Consequently

> One of the most striking features of consciousness is its discontinuity—as revealed in the blind spot, and saccadic gaps, to take the simplest examples. This discontinuity of consciousness is striking because of the *apparent* continuity of consciousness (Dennett 1991, p. 356; Dennett's italics).

On this view, consciousness is discontinuous and fragmented, and what it actually presents to us at any given time are small, disconnected snapshots.

Does the refrigerator light response apply to the unity of consciousness over time? Let us come back to the example of a melody. When we consciously hear the C at the end of A-B-C, our conscious experience is different from that of a C that follows nothing. Or at least so it seems.

The refrigerator light explanation of this kind of experience might go something like the following. The A and B only seem to be a part of our conscious experience of the C at the end of A-B-C. In reality, the mental qualities of A and B do not feature in conscious experience of the C at all. At best, they are labeled by the brain in a generic way, perhaps as <the sounds that just passed.>

There is at least one reason to think that it is not the case. If the temporal version of the refrigerator light story is true, then we would have no way of making the conscious discrimination between a melody and series of random sounds. Music appreciation, if it was even possible, would have little to do with hearing the music.

But we surely hear music even if we do not know how to think about it. Sydney Shoemaker makes the point in the following way: "it is essential to the awareness of the melody as *that* melody (…) that one be aware of the relationship between the different notes (…). And this requires unity of consciousness—the co-consciousness of the experiences of the different notes [over time]" (Shoemaker 2003, p. 65). It is these relationships between the notes that make the conscious experience of the melody what it is.

Bracketing what co-consciousness amounts to, Shoemaker's point is that perceiving temporal extension is essential in the task of individuating different melodies. Normally, we can discriminate an experience of A-B-C from an experience of B-A-C. However, if the temporal ordering of A* and B* make no auditory difference to how we consciously experience the C*, as the temporal version of the refrigerator light story would seem to suggest, our conscious experience of the C would be the same in either case.

The temporal version of the refrigerator light story gets rid of the contribution that conscious experiences make to the present. And that leaves mysterious how we distinguish between different melodies. But, as Shoemaker observes, we can and do make such discriminations perceptually. Arguably, we can make them even without having any notion of notes, music, and so on.

Past conscious experiences are still beyond the kind of access that we have to the contents of present conscious experiences. So, on the one hand, our conscious past contributes to the qualities of the conscious present, but, on the other, it is out of reach. Inspired by Ned Blocks's distinction between phenomenal and access consciousness, one may think that this is an instance of phenomenal consciousness that extends beyond access consciousness in a kind of phenomenal overflow (Block 2011).

Much has been said about whether consciousness extends beyond access in the way that Block suggests and it is beyond the scope of this paper to address it here (Brown 2012; Cohen and Dennett 2011; Kouider et al. 2010). I mention the distinction between phenomenal and access consciousness only to point out that nothing in the temporal qualities model depends on the existence of phenomenal overflow. We do not need to accept Block's distinction in order to go along with the model of temporality I offer here. Even though the temporal version of the refrigerator light story does not work, this does not mean that the opposite view is true.

This is because the temporal qualities and the relations they bear to other qualities of the same kind are instantiated in a single perception. Being aware of that one perception in an appropriate way results in the kind of phenomenology we associate with temporal extension. When we are aware of the temporal qualities instantiated in the perception our conscious experience will feature these qualities—nothing is left out.

Conscious experience of temporality can result from us being aware of just one perception. In Block's terms, we need be access conscious of just one perception to experience it as extended in time. All we need is to be aware of are the temporal qualities featured in the perception.

Phenomenology squares with the standard characterization of the stream of consciousness. But we need not take this appearance to reflect reality. Conscious experiences can themselves be "chopped up in bits" and not flow, as James and others suggest. Rather, they are momentary snapshots, albeit indistinct and incomplete ones, which are related to other such snapshots via their temporal qualities.

The model of temporal qualities I offer here implies that individual conscious experiences appear unified by relations between individual temporal qualities. Conscious experiences appear to be extended in time because we are aware of mental qualities as related to each other in an appropriate way. And our conscious experiences appear to pass in time because the past is not present except as mere relata in those relations.

6.2 Features of the View: Two Levels of Error

The account given in Chapter 3 and Chapter 5 can shed new light on various temporal illusions discussed in the empirical literature, such as temporal ventriloquism, the odd-ball illusion, or the phi phenomenon. The model predicts that there are at least two ways in which a conscious experience of time can misrepresent the temporal properties in the environment. In other words, there are two ways in which temporal illusions can arise.

One is at the level of perception, where a sensation instantiates a mental quality that does not correspond to the property instantiated in the environment. In this case our awareness of represents our sensation accurately, even though the sensation itself is inaccurate. The result is a temporal illusion.

Another way one could have a temporal illusion is if it occurs only at the level of conscious experience. In this case, a mental quality accurately reflects a temporal property in the environment.   However, the temporal quality is mischaracterized by our awareness. The result is also temporal illusion.

Technically, there is a third possibility, in which both the sensation and our awareness are inaccurate. However, distinguishing this case from the other two in practice would be very difficult. So as far as this model is developed here, this possibility can be ignored.

But there is a way to distinguish illusions at the level of sensations from those that are purely at the level of conscious experience. Temporal illusions solely at the level of conscious experience would be more likely to manifest themselves only in verbal reports. And temporal illusions at the level of conscious experience would be more likely to affect verbal reports and also non-verbal behavior that independent of cognitive control.

This has implications for experimental design. Temporal ventriloquism, for example, could turn out to be strictly a perceptual illusion. Or it could be an illusion of conscious experience alone. Experiments driven by the theory presented in Chapter 3 and Chapter 5 would control for this distinction.

Ultimately, this suggests that we need distinct neurobiological accounts of the mechanisms of time perception and conscious experience of time.   Among them are various inner clock models, which posit a dedicated time mechanism, often in the cerebellum and the basal ganglia (Rammsayer and Ulrich 2001; Ivry 1996; Miall 1989; Wearden et al. 1998; Treisman et al. 1990; Gibbon 1977; Creelman 1962). Alternatives to the dedicated models posit distributed mechanisms that keep track of energy levels in neuron populations or patterns of neural activation (Mauk and Buonomano 2004; Karmarkar and Buonomano 2007; Pariyadath and Eagleman 2007).

It is important to note that the two-part theory offered here is not meant to be in competition with those or any other neurobiological hypotheses. The quality space model is stated at the psychological level of description, not at the neurobiological level. It explains the phenomenology that people report on, and gives a model on mental qualities that can explain temporal perception independently of that phenomenology.

However, if the view offered here is correct, we have an important methodological constraint on future research into temporal perception and conscious experience of time. We have to assume that some of the experiments presented as support for the abovementioned neurobiological hypotheses about temporal perception, might actually be addressing a related, but distinct process of consciousness of time. Adopting the framework I offer would, hopefully, result in better experiment design and a better sense of the distinction between temporal perception and consciousness.

6.3 Features of the View: Folk Metaphors of Temporal Experience Explained

The vagaries of conscious experience of time are an important part of our folk conception of consciousness. It is generally accepted folk wisdom that time appears to go faster when we are having fun, and it appears to slow down when we are engaged in something monotonous or boring. And people often use metaphors when reporting on their temporal experiences, such as “lost myself in my work,” “let the time fly by,” and “time dragged on.”

The two-part model presented in Chapter 3 and Chapter 5 makes sense of these metaphors. And just as with temporal illusions, the sense of time speeding up or slowing down can be the result of one of two mechanisms. It could be the result of a sensation instantiating a mental quality that does not correspond to any temporal property in the environment, or the result of the way that our awareness characterizes that sensation.

Normally, when one has a conscious temporal experience, our awareness characterizes a sensation as instantiating temporal qualities, such as timing* and duration*. But if there is a mismatch between the qualities that sensations are actually instantiating and the way our awareness characterizes them, time could seem to drag out or speed up.

6.4 Features of the View: Subjects and Selves

The dim view of the unity of consciousness I offer in section 6.1 puts a constraint on our conception of the subject (or self). It also has implication on the problems of personal identity at and over time. Arguably, it suggests that philosophers have been addressing the problems of personal identity in the wrong way.

Derek Parfit, among others, has argued that personal identity is satisfied by psychological continuity (Parfit 1984). This is the continuity that binds thoughts about apples, for example, with thoughts that immediately follow them. According to Parfit, This sort of causal and functional continuity between various mental states is all there is to personal identity over time.

The alternative and more popular view accepts the ego as the criteria for personal identity. On this view, personal identity is satisfied the subject that has a conscious mental life. The functional relations between individual mental states are not relevant, on the ego criteria. What matters is that the same subject has the experiences.

As a test case Parfit imagines a machine that could transport information about the arrangement of every molecule in a person's body to a distant planet via radiowaves (Parfit 1995). Once this information is received another machine uses it to build a molecule for molecule replica of the person. Finally, once the person is scanned and information about that person is sent, the original on Earth is destroyed.

The question is whether the person constructed on another planet is continuous with the person scanned on Earth, or whether they are just a replicant clone. How one answers this question depends on one's prior philosophical commitment about personal identity.

The ego theorist will say that the person constructed on a distant planet is not continuous. This is because the destruction of the original destroys the ego. Therefore, teleportation does not preserve personal identity.

The psychological continuity theorist, however, seems to be in a position to accept that the reconstructed personal on a distant planet is continuous with their counterpart on earth. This is because they are psychologically continuous with that person, in that they maintain their mental states, dispositions, memories, and so on. On this view, teleportation preserves personal identity.

On the view I present the unity of conscious experiences is irrelevant to the unity subject (or self). Given this, the offered view is not compatible with the ego-criteria for personal identity. Theories of personal identity that rely on the ego are therefore at a disadvantage, if the framework given here is correct.

Of course, that does not mean that we do not have a distinct sense that conscious experiences are unified as pertains to the subject. It just does not play a role in unifying experiences. According to Rosenthal, for example, what is responsible for that sense is a disposition to identify oneself as the person that has a particular conscious experience (Rosenthal 2005). And this identification is based on a cluster of beliefs one has accumulated about oneself over a lifetime.

CHAPTER 2: Temporality: a Historical Perspective

1.1 Experience of the Passing of Time

Typical examples of the experience of the passing of time involve a melody. When we consciously hear successive notes A, B, C, played on a flute each of those experiences presents us with a distinct auditory quality of A*, B*, and C*.[2] And when the C note sounds at the end of the A-B-C melody, we have a distinct kind of experience from the one in which we only hear the C. The final note is presented in our conscious experience as itself, that is, as a C, but also as a part of a melody A-B-C.

The reason why we can experience the C as a part of a melody is that we can perceive things as having temporal extension. Or, as Ian Phillip puts it "more generally, the datum is this: there are cases … in which one hears or perceives in such a way that one is able to attend to a structure of notes, events or event parts which occupy a temporal interval" (Phillips 2010, p. 178). If we heard the melody without being able to attend to its structure, then we would miss out on what makes listening to music worthwhile. We would never be able to consciously experience, among other things, the distinct auditory quality of a flute C following a flute A and a flute B.

Conscious perceptual experience of that simple melody will involve the mental qualities of the individual notes heard at that moment. The temporal aspect of conscious experience allows the notes that passed to contribute, somehow, to the experience of the melody as such. How this can be the case, meaning, how we can

[2] To make things easier, I am using a star to designate a mental quality as opposed to a perceptible property. So, a P* is in my mind while P is out in the world.

experience temporal extension, given the momentary nature of individual conscious experiences is sometimes referred to as the problem of temporality (Kelly 2005).

One feature that makes it possible for us to experience a melody as such is the temporal extension of individual tones. Without that feature, our conscious experience of the melody would lack its distinct temporal dimension and would appear to be a mere succession of otherwise disconnected tones. And what is true of a conscious experience of a melody holds also for all conscious experiences of succession.

Many if not all conscious experiences appear to have a temporal dimension to a greater or lesser extent. Even the conscious experience of a still scene has a temporal extension that can alter the way that the scene is experienced. Looking at the same scene for an hour has an experiential quality that looking at it for a second does not.

But merely pointing out that the experience of the passing of time is a distinct aspect of our phenomenology does not yet tell us what it consists of. And as soon as we try to characterize it, problems arise. The most important of these problems is an inherent contradiction in the notion of a conscious experience of temporal extension.

While we have a sense of the temporal extension of our conscious experiences, one undeniable aspect of any conscious experience is that it appears to occur in the present. We do not consciously experience the past alongside the present, but just whatever is happening right now.

On the one hand, when we consciously experience a melody being played on a flute, our experience is of the individual tones being played. On the other hand, we also have the sense of temporal extension, which comes from our conscious experience of succession. So, somewhat paradoxically, the experience of the passing of time does not change the quality of tones that we hear in any way, but makes a salient qualitative difference to how we hear them.

Conscious experiences also appear to be seamlessly continuous. From one moment to the next, each conscious experience appears to be connected to the one that preceded it in what has often been described as the stream of consciousness. The flow of this stream is one of the most salient phenomenological features of our conscious lives.

Descriptions of the experience of the passing of time and the experience of continuity constitute a straightforward theory of the phenomenology of unity of consciousness over time. The sense that our consciousness is extended in time and also seamlessly continuous just *is* the sense of unity of consciousness over time, as some of the philosophers I mention below maintain. Without these phenomenological features, one might suppose, our conscious experiences would appear to be fragmented and disjoint. But this straightforward characterization of the unity of consciousness over time faces difficulties that it partially inherits from the problem of how the conscious past can feature in the present.

The problem for the straightforward characterization of the unity of consciousness over time comes in what Sean Kelly calls the Puzzle of Temporal Experience. According to Kelly, the puzzle can best be summarized as a question:

> How is it possible for us to have experiences as of continuous, dynamic, temporally structured, unified events given that we start with (what at least seems to be) a sequence of independent and static snapshots of the world at a time? (Kelly 2005, p. 209)

Arguably, the Puzzle of Temporal Experience is a problem only for theories of consciousness according to which conscious experiences are distinct and independent static snapshots, that is, atomist theories of consciousness. In Chapter 1 I characterized this problem as the second phenomenological sub-challenge to atomism.

The seeming continuity of consciousness from one moment to the next appears to be a serious problem for any atomist conception of conscious experience. The puzzle is especially pressing since the sense of continuity is ubiquitous. Normally, our conscious experiences appear to be a seamless and continuous stream.

The Puzzle of Temporal Experience and the problem of charactering the experience of the passing of time are closely related. Both problems are connected to the straightforward phenomenological characterization of the unity of consciousness over time. And both problems can be understood as a particularly pressing problem for atomism. This is because according to atomism, successive conscious experiences are distinct from each other. So, while the datum is a phenomenology of unity, which involves the experience of succession and continuity, our conscious experiences, according to atomism, are successive, distinct snapshots.

In sections 2, 3, and 4 of this chapter I present a range of theories of the experience of succession, which aim to reconcile the phenomenology of unity with an atomist conception of conscious experience. In light of the difficulties I just mentioned, some of these theories drop atomism in favor of an alternative conception of conscious experience. On these views, the phenomenology of unity is explained by an intrinsic unity of consciousness.

This move leads to a problematic view of the relationship between conscious of experience of time and the timing of the mental states that underlie it. On this view, the timing that we consciously experience is determined by the timing of mental states that underlie that very experience. The temporal aspect of conscious appearance is, on this view, the best and perhaps only guide to the underlying temporal aspect of mental reality.

In section 5 I present an argument against this claim. The foil is Daniel Dennett's and Marcel Kinsbourne's postdictic account of temporal anomalies of conscious experience, such as the color-phi phenomenon. I side with Dennett in thinking that temporal anomalies render the conception of temporal experience held by many of the theories I discuss in sections 2, 3, and 4 untenable.

Finally, I conclude with remarks about representational atomism and the unity of consciousness over time. I urge that that, contrary to the majority view, representationalist atomism can yield a phenomenologically adequate characterization of the unity over time. The job of giving a theory of what underlies that phenomenology I leave to chapter 3, 4 and 5. I will give a theory of how we perceive duration in chapters 3 and 4 and then move onto the phenomenology we encounter in conscious experience in chapter 5.

2.1 Constructivism

Constructivism is the label I will use throughout this discussion for a view that the experience of succession is made up out of multiple conscious experiences that by themselves are not sufficient to produce an experience of succession. Typically, constructivism takes for granted that experiences are snapshots. A constructivist theory then adds some process or property that brings the stills together and results in the kind of temporal extension necessary for the experience passing of time. Constructivist views differ in what kind of process is needed to reach this result.

The following are some of the historically important constructivist theories. They do not exhaust the logical space of possible constructivist views but can serve as representatives of various strategies that can be used to explain the experience of the passing of time. Given this, the points I make here can be probably extended to cover the constructivist theories that I do not mention.

2.2.1 David Hume

One possibility is that we believe or infer things about time, but we do not perceive it. This line of thinking finds its origin in David Hume, who suggested that "as 'tis from the disposition of visible and tangible objects we receive the idea of space, so from the succession of ideas and impressions we form the idea of time" (Hume 2000/1739, p. 35). On Hume's view, we are disposed to infer the experience of temporal extension from the succession of experiences. Hume uses a similar explanation in his celebrated theory of cause and effect.

But, contrary to Hume, there is at least one good reason to think that we do not simply infer the idea of time. Evidence against this view can be found in motion blindness, or akinetopisia, as this condition is sometimes called. Motion blindness is an extremely rare disorder caused by the malfunction or lesion of area V5 (MT) in the visual cortex. This area of the brain has been identified as crucial to processing visual information about motion (Zeki 2004, 1991; Beckers and Zeki 1995).

Motion blindness causes one to have experiences that are a series of disconnected stills. What is functionally impaired in people with V5 (MT) damage is their ability to discriminate the timing of the onset and offset of properties in the world altering their perception of motion. Their temporal discriminations are very coarse-grained. Consequently, it becomes near impossible to perceive the duration of things.

What this suggests is that damage to the visual system and specifically to area V5 (MT) causes deficits in the accurate perception of the duration of events. But, importantly, area V5 (MT) is not directly involved in inferential reasoning—it is a dedicated part of the visual system. So, a person affected by motion blindness, if they are not also cognitively impaired, can perform a range of inferences.

Presumably, they can also form beliefs that the succession of their still experiences corresponds to a succession in the things they perceive in the world. A still of an object at one position, followed by a still of the same object at another position is, all things being equal, enough to infer that the object moved. Nonetheless, they do not thereby gain the ability to experience duration in the way that we do.

So, even though the motion-blind can make the kind of inferences that Hume describes, they cannot perceive duration in the way that we do. And it seems that the reason they cannot is connected to their perceptual deficit. It is therefore safe to think that Hume was wrong about the experience of time being constructed out of an inference.

2.2.2 Immanuel Kant

Similarly to Hume, Immanuel Kant does not think that time can be an object of perceptual experience. Kant thinks that

> Time cannot in itself be perceived, and what precedes or follows cannot be determined by reference to it in the object (…) I am, therefore, conscious only that my imagination places one state before and the other after, but not that the one state precedes the other in the object (Kant 1929/1781, B233-4; also look A123-4).

Here Kant urges that nothing about what we experience can inform us about which state of the object came before another. We construct time internally only after interacting with the world.

On Kant's view, memory is essential in the internal construction of time. Kant tells us that:

> When I (…) think of the time from noon to another [hour] (…) obviously the various manifold representations that are involved must be apprehended by me in thought one after the other. But if I were always to drop out of thought the preceding representations (…) and did not *reproduce* them while advancing to those that follow, a complete representation would never be obtained (Kant 1929/1781, A102; my italics).

On this view, the experience of time is built up by a process that *reproduces* the experiences one just had. We construct an experience of a melody by reproducing the past experiences of individual notes.

While there is no question that some form of memory (at least iconic memory (Coltheart 1980)) is involved in normal perception, Kant's constructivism about temporal experience is fundamentally wrongheaded. Contrary to Kant, the reproduction of experiences is not the same as experiencing them. Remembering something that just happened and the experience of something that is happening now are distinct, both theoretically and phenomenologically.

When we are listening to a melody and experience it as such, we can, while engaged in that listening, remember one of the notes that just sounded. We could even reproduce that past experience, with a certain amount of effort of imagination. However, the phenomenology that accompanies remembering the note will not present it as a vivid auditory experience, but as a memory of one, which will be disconnected from the note being listened to at that very moment.

It would be a miracle if remembering the note could incorporate it into our present experience to result in the experience of the melody as such. When we reproduce past experience, our phenomenology presents the reproduction simultaneously, but distinctly from whatever we are consciously experiencing at the moment. Simply put, Kant's view gets the phenomenology wrong.

Furthermore, Kant's view is shaky on empirical grounds. Brain structures involved in memory retrieval, such as the hippocampus, are not involved in perception, and, conversely, perceptual areas such as the visual or auditory cortices are usually not involved in the retrieval of memories. Overall, memory retrieval is a distinct mental process from perception, even though these processes clearly can inform each other.

Surely, amnesiacs and people that have problems with memory retrieval can experience melodies as such and therefore also succession as such.

2.2.3 Franz Brentano

Franz Brentano’s account superficially resembles Kant’s in that it appears to involve memory. According to Brentano, past experiences remain as a part of the present experience and together with the present experience constitute an experience of succession. However, unlike Kant, Brentano does not rely on the notion of reproduction or recollection of past experiences.

Instead, Brentano describes a unique psychological process he calls proteraesthesis, which operates very much like a short-term memory buffer (Jensen and Lisman 1998). Roderick Chisholm explains that proteraesthesis is

> a necessary accompaniment of every sensation. Indeed, Brentano says that sensation exists only as the *boundary [Grenze]* of an experience of proteraesthesis (Chisholm 1981, p. 7; Chisholm's italics).

On this view, successive conscious sensations are temporal boundaries of proteraesthesis in the same sense that colors are the spatial boundaries of shapes.

So, according to Brentano, we need at least two conscious sensations occurring in succession in order to have an experience of succession. But pointing out that sensations are the boundaries of proteraesthesis does not explain the role that these consciousness play in constructing the experience of succession. What needs explaining is the experience of succession itself, not the conditions for its possibility.

Unfortunately, Brentano's views about this changed over time. Brentano's early view is that past conscious experiences are merely non-existents, which are modified by the adjectives "past" and "future." So, on this view, proteraesthesis contributes to experience through a modified intentionality about the past sensation (Chisholm 1981, p. 8). This intentionality is modified in that it is directed at an already non-existent past sensation of something else.

On this view, experience of succession involves a special kind of thought about the past. So we are not presented with a past experience again, but rather with the contents of a thought about it. And this is good news, since proteraesthesis should not be the reproduction of past experiences in consciousness, as on Kant's view, and it should also not be the retention of past experiences as if they were afterimages, which is contrary to normal experience.

However, there is a problem with the modified intentionality model. A thought about an already non-existent sensation of a tone and a sensation of a tone itself will appear very differently in conscious experience. But the succession of conscious sensations presents a seamless continuum, that is, the apparent stream of consciousness. So we are left to wonder how heterogeneous mental states such as thoughts and sensations could compose the seamless and seemingly continuous experience of succession.

Confronted with this difficulty Brentano introduces further refinements to the notion of proteraesthesis. First, instead of a special intentional relation to the past sensation, Brentano now insists that the object of the past sensation is present in experience in the same way that a sensation is present in experience—this resolves the problem of continuity.

Unfortunately, Brentano new theory is not much of an improvement, as it raises a separate difficulty. If the object of the past sensation is presented in the present conscious experience, we need to know why proteraesthesis does not present us with ghostly afterimages. This would be contrary to normal conscious experience.

To resolve this difficulty, Brentano urges that past sensations present their sensory object in a different mode of presentation than present sensations. On this view, past tones of a melody, for example, are parts of the present experience of the melody by being presented in the just-past mode of presentation (Mulligan 2004, p. 79-80). Given this, Brentano thinks that past sensations can form a continuum with present sensations.

On this view, past conscious experience form a continuum with present conscious experiences and are the boundaries of the experience of proteraesthesis. Whatever we make of this view, it has an important implication about the relationship between conscious experience of succession and the mental states that underlie it. On Brentano's view, conscious experience of succession depends on the succession of conscious experiences.

In short, Brentano claims that the temporal succession of sensations of the tones of a melody, for example, determines the way in which those tones will be experienced as a part of the melody. And, importantly, the order of the sensations of the tones determines the way in which the melody itself will be experienced. This thesis is important in the subsequent discussion, so I will label it:

(D) What underlies the experience of succession is the temporal succession of conscious experiences

Adopting thesis (D) has important consequences for how we conceive of mental time. For example, take the sequence of tones A at t1, B at t2, and C at t3. On Brentano's same-order theory of consciousness, the conscious sensation of C at t3 presents C as the primary object, and the act of sensation as the secondary object (Textor 2006). In addition, on account of Brentano's proteraesthesis, at t3 A and B are also presented as primary objects of the conscious experience, but in the just-past mode of presentation.

Because of (D), the order in which A and B occurred determine how they are experienced at t3. The sequence A-B-C is experienced differently than the sequence B-A-C, and this experiential difference is determined by, on Brentano's view, by the order the sensations of the tones. The boundaries of proteraesthesis are determined by the temporal order of conscious experiences.

Importantly, thesis (D) can be contrasted with the claim that all that is needed to explain experience are the representational properties of mental states. This view is committed to the following two claims:

(R) Conscious experience of succession is the result of the content of conscious mental states

and its generalized version:

(R*) Phenomenology (in general) is determined by the content of conscious mental states

Claim (R*) is usually endorsed by philosophers interested in explaining consciousness in terms of representation (Rosenthal 2005, Chapter 1; Tye 2003, p. 36; Dennett 1991, p. 46, 147-8).

Claim (D) implies that it is the temporal properties of mental states that determine the temporal phenomenology of conscious experience, not how temporal properties are *represented* by these mental states. Both (R*) and (R) are incompatible with (D), which is endorsed by Brentano, as well as many other theorists whose views are addressed below. The experience of succession, according to (D), is tied to the timing of occurrence of mental states, not the timing that they represent.

It should be noted that there are independent problems that can be raised for the all the views presented here. But addressing these difficulties in detail is beyond the scope of the present discussion. In the context of the present work a commitment to (D) is sufficiently problematic, as I will argue in the last sections of this chapter.

2.2.4 Edmund Husserl

Edmund Husserl is also a contructivist. Husserl's first theory of the experience of succession introduces the notions of protentions, which are experiences one is about to have, and retentions, which are experiences just past. Protensions and retensions are quasi-contentful representations that flank what Husserl calls the primal impression (or datum) of conscious experience. As with Brentano's theory, we can think of these as contents of a short-term memory buffer.

These three notions comprise the structure of any conscious experience and account for its temporal dimension. The primal impression is the cusp between the past and the future and, as long as it is at this cusp, it does not represent anything at all. Retentions and protentions sandwich the primal impression, and together form the experience of succession as such.

Retentions are primal impressions that recede into the past, but are nonetheless a part of present experience:

> When a primal datum, a new phase, emerges, the preceding phase does not vanish but is 'kept in grip' (that is to say, precisely 'retained') (Husserl 1991/1917, p. 118).

On this view, the just-had experience remains in consciousness and continues to influence incoming experiences.

Similarly to retentions, protentions influence the experience we are about to have. Husserl explains that:

> The preceding protention intentionally contains all the later in itself (implies them); the succeeding retention intentionally implies all the earlier ones (Mensch 2003, p. 71f4; translation of Husserl's manuscript L I 16, p. 6a).

On this view, protentions are representations of the near future, which are the result of perceptual learning.

All of this fits together in a straightforward way. Take as an example a blue experience followed by a green experience. On Husserl's view, at the time that one has an experience of blue, protention contains green. As time passes, the green content makes it from protention to primal impression, and the blue content recedes into retention. The retention-primal impression-protention sandwich of blue and green contents is present all at the same time, and it is this presentation, together with the relative fading in and out of blue and green, that composes the temporal horizon on which we have the experience of succession.

In Figure 1 below, the x axis represents time and the arrow on the x axis represents the direction of time. The y axis represents the contents of the subjective present. Everything to the right of the y axis is in protention, and everything to the left of the y axis is in retention. The "green" experience fades into the present experience out of protention and the "blue" experience fades out of the present experience into retention.

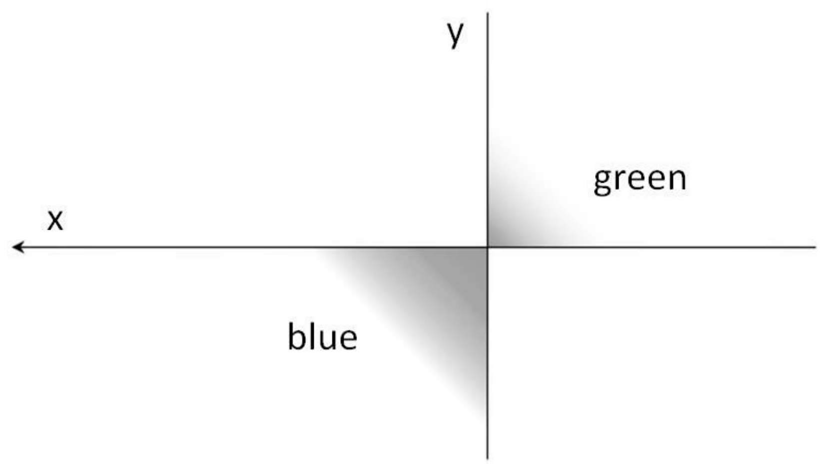


Figure 1. Edmund Husserl's retention-primal impression-protention model.

But Husserl's retention-primal impression-protention model faces a difficulty. The theory implies that at any given time, a single moment presents one with experiences that have just passed and with experiences one is about to have. This is not what normal experience is like. Seeing some blue followed by some green does not result in the blue sticking around in experience as the green fades in. We see a succession of colors, not an apparition of what we've seen fading out as the next color fades in.

Consequently, while Husserl's theory yields an account of the experience of succession, it also implies that experience presents us with trails of moving objects and chords instead of melodies and is thereby phenomenologically unsustainable. Since this problem will play an important role in subsequent discussion I will reference it as such:

(PDE) Any experience of succession requires at least one successive experience to be presented at least twice

As noted above, (PDE) is phenomenologically implausible. We are not presented with two or more instances of the same experience—even if the second presentation appears differently via fading or other such change.

(PDE) is addressed by most of Husserl's commentators and Husserl himself seems to have been aware of it. Presumably it is (PDE) that leads Husserl to eventually nuance his original retention-primal impression-protention theory and specify more distinctly what he means by 'intentional implication' and 'intentional containment.' On this later theory, Husserl proposes that retentions and protentions are structural features of experience, but are not themselves experiences.

Shaun Gallagher sheds light on the notion of intentional containment and implication in the following way: "Retention, according to [Husserl's] later theory, does not retain real contents; it retains intentional contents. It retains the sense (the meaning content) of what has just consciously passed (…) retention is not something that is apprehended; it is a part of the structure of apprehending, if by that we mean awareness" (Gallagher 2003). What this suggests is that past experiences are more like thoughts than perceptions. Intentional containment involves intentional contents about the past.

But each of the parts of a single conscious experience—retention, protention and primal impression—are not just thoughts. That would be like having two thoughts and a perception simultaneously, which on its own would not be enough. As mentioned in the discussion of Hume above, merely thinking about the past is not sufficient to have an experience of temporal extension. So there must more to intentional containment than just intentional content.

Indeed, Husserl conceives of retentions as containing the full tri-partite structure of the past experience. The different parts of the retention-primal impression-protension sandwich are structural features that comprise every conscious experience.

> In this way, it becomes evident that concrete perception as original consciousness (original givenness) of a temporally extended object is structured internally as itself a streaming system of momentary perceptions (so-called primal impressions). But each such momentary perception is the nuclear phase of a continuity, a continuity of momentary gradated retentions on the one side, and a horizon of what is coming on the other side: a horizon of "protention," which is disclosed to be characterized as a constantly gradated coming (Zahavi 1999, p. 54; translation of Husserl's manuscript IX, 202 in Husserl-Archive).

This recursive structure of the retention-primal impression-protention sandwich then forms an intentional horizon of our conscious experience. But how does it do that?

Dan Zahavi explains: 'The relations between protention, primal impression, and retention are not relations among items located within the temporal flow; rather these relations constitute the flow in question' (Zahavi 2007, p. 468). Zahavi's point is that the intentional relations are not merely contents of conscious experiences, but something more like vehicles of those conscious experiences. On this view, there are no lingering colors and sounds in present experience because past conscious experiences are present as structural parts of the conscious experience we having right now.

One virtue of this view is that, unlike Hume's, it addresses the problem of how we perceive temporal extension. Husserl's answer is that we perceive it because of the tri-partite structure of conscious experience. This view can also explain why we hear the C at the end of A-B-C as different from a single C. In short, in the first case, the A and the B are a part of the structure of the conscious perception of C while in the second case they are not.

However, the disadvantage of the view is that it involves a lot of conceptual machinery that we are given little independent reason to accept. As Sean Kelly puts it, with Husserl's view "we have no interesting account of what it is now to experience something *as just-having-been*, except to say that it is the phenomenon involved in the experience of the passage of time. But this is the phenomenon we are trying to *explain*. It does no good just to give a name to its various parts" (Kelly 2005, p. 226; Kelly's italics). Kelly's point here is that protentions, retentions, and primal impressions are just names for the temporal features of perception we want to explain. They are not themselves the explenans.

And why should we suppose that consciousness is constituted by retention, protention and primal impression to begin with? There seems to be no way to verify Husserl's theory empirically, since the structure that Husserl attributes to conscious experience is merely intentional. There are some attempts to make the connection between Husserl's views and empirical hypotheses (Lloyd 2011; Varela 1999). But whether these are successful is contentious (Lee 2012; Grush 2006; Klincewicz 2012)

Importantly to the issues at hand, Husserl's nuanced later view commits him to (D), which is the problematic thesis about of the close relationship between experiences and the mental states that underlie them. This is because Husserl's view is that the succession of protentions, primal impression, and retentions is itself responsible for the experience of temporal extension we experience when we hear a melody. So, on Husserl's new view, the succession presented in experience is at least in part constituted by the properties of the mental states that underlie it (also look: Grush 2006). Characterizing protentions and retentions as structural features of experience saves Husserl's view from (PDE) but leads him into thesis (D).

3.1 Primitivism

Contrasted with constructivism, primitivism is the claim that succession can be featured in a single experience just like other mental qualities, such as color or sound. On some versions of primitivism, conscious experiences have temporal properties such as succession because they are themselves extended in time. On others, a theory of temporal extension just is a theory of conscious experience.

3.2 Henri Bergson

Henri Bergson's primitivism rests on the sharp distinction between how we conceive of space and how we conceive of time. Space, according to Bergson, is conceived of as a homogenous medium in which individual objects are located. Time, on the other hand, is heterogeneous. To draw the contrast, Bergson points out that:

> Material objects, being exterior to one another and to ourselves, derive both exteriorities from the homogeneity of a medium which inserts intervals between them and sets off their outlines: but states of consciousness, even when successive, permeate one another (Bergson 2001/1913, p. 98).

So, according to Bergson, the difficulties found with explanations of the experience of succession are really pseudo-problems. The culprit here is an illegitimate use of spatial metaphors to describe time, which is fundamentally unexteded.

On this view, it makes no sense to describe objects as located in time. The world exists only in the present, and each successive moment brings with it the total annihilation of the world. Consciousness, somehow, endures through this annihilation. "If consciousness is aware of anything more than positions, the reason is that it keeps the successive positions in mind and synthesizes them" (Bergson 2001/1913, p. 111). And through this synthesis consciousness constructs time itself.

At this point it might seem that Bergson's view is a form of constructivism. But that is actually not so. Bergson tells us that:

> It is enough that, in recalling these [past] states, [consciousness] does not set them alongside its actual state as one point alongside another, but forms both the past and the present states into an organic whole, as happens when we

> recall the notes of a tune, melting, so to speak, into one another (Bergson 2001/1913, p. 100).

So, on this view, the mere absence of space is sufficient for the formation of the organic whole that constitutes an experience of a melody as such. Bergson's view is primitivist, in that the organic whole is itself constitutive of the experience of succession.

Even if we grant all of Bergson's claims, the experience of succession is not yet completely explained. The heterogeneity of time does not in itself explain why a succession of tones is experienced as a melody. Here, Bergson tells us that "it is because I *endure* in this way that I picture to myself what I call the past oscillations of the pendulum at the same time as I perceive the present oscillation" (Bergson 2001/1913, p. 108; Bergson's italics). The succession of tones (or swings of a pendulum) intermingles into the organic whole that Bergson envisions on account of it being experienced by a single enduring self. Bergson view, therefore, implies that self is outside of space and, by corollary, non-physical.

Again, Bergson's observation is that spatial metaphors are misleading. Once we cease to be led astray, we should see, Bergson claims, that there are actually no individual mental states at all and we can make sense of his view.

> In reality, our [experiences] are continually in flux, and that while it is possible to distinguish different 'tones' to our inner experience, there are, in actuality, no distinct boundaries within consciousness (Barnard 2010, p. 46).

But aside from the metaphors of interconnectedness and the organic whole, there is little that Bergson offers as an alternative. And there are independent issues, even if these metaphors can be expanded into metaphysical theories.

First, the dominant view of the relationship between space and time in post-Einsteinian physics posits a complex manifold—a spacetime—instead of two distinct dimensions, one for time and one for space (Einstein 1905; Minkowski 1923/1908). It is not obvious how Bergson's sharp distinction between the temporal and spatial dimensions can be made in context of that view. However, there are many interpretations of spacetime, so it is possible that one of them is compatible with Bergson's view, even though that itself is controversial (Dorato 2006). It is also possible, I suppose, to divorce Bergson's theory of conscious experience from his metaphysics of space.

Secondly, the view that the self, if there is such a thing, is a non-physical substance has well-known problems, which I feel I do not have to rehearse here. In short, substance dualism contradicts the second law of thermodynamics. A commitment to this view might alone be sufficient to disqualify Bergson's theory.

And even if Bergson is right and the self not physical, there remains the theoretical problem of explaining how a non-physical thing could synthesize successive sensations into an experience of succession. So Bergson's explanation turns out to be purely stipulative. Given all of this, I take it that Bergson's theory should be rejected, even if it can offer an otherwise complete explanation of the experience of succession.[3] Unless we already hold most of the assumptions Bergson takes for granted to be true, his view is not of much help in understanding temporality.

[3] Regardless, the view I will present in Chapter 5 can be construed as Bergsonian. On the view I will advance there, the temporal aspect of experience is purely qualitative.

3.3 William James

William James is probably the most paradigmatic primitivist. James argues that any single present experience is composed of a bundle of experiences. Together these bundles constitute the specious present. This present is specious because it "is really a part of the past—a recent past—delusively given as being a time that intervenes between the past and the future" (James 1890, p. 609). So, on James's view, a present conscious experience is actually in the past, with some past experiences tacked on to it.

On this view, conscious experiences appear extended in time and have an intrinsic directionality. So, according to James, any single conscious experience is like a boat, with a bow and stern and middle deck. The specious presents extends over this bow, stern, and middle deck resulting in an experience of succession.

James's theory resembles Husserl's later view, in that conscious experiences are tri-partite structures. James, like Husserl, thinks of conscious experiences as having a front, back, and middle. However, there are important differences between Husserl and James, which override these superficial similarities.

First, on James's view, conscious experiences are captured into a frame of the specious present, which encompasses a variable period of time, up to a minute in duration (James 1890, p. 642). This is not what Husserl thought. For Husserl, the retention-primal impression-protention is a necessary and constant structural component of any conscious experience and does not itself vary in size.

Secondly, the frame of the specious present is not a memory buffer, which is what Husserl's view suggests. James does not think that past experiences are held for a time in a special sort of intentional relation. For James, the horizon on which a variable number of successive experiences can be laid out is the experience itself, not an additional mechanism or structure.

Finally, James presents the specious present theory as a phenomenologically viable alternative to constructivist views, which he thinks liken consciousness to “a glow-worm spark, illuminating the point it immediately covered, but leaving all beyond in total darkness” (James 1886, p. 375; 1890, p. 606). If the glow-worm conception was true, we would be unable to function, very much like someone affected by motion blindness, always stuck in the present, and unable to think or perceive anything at all—or so James thinks.

James’ view sits squarely in the camp of theories that explain the experience of succession by appeal to thesis (D). According to James, the experience of succession is the result of a structure of the mental state that underlies it. The ordering of the parts of a particular conscious experience, that is, the direction of its bow, stern, and middle deck, determines its temporal dimension.

Whatever we make of James’s view, it can account for how an experience of a melody as such is possible: up to a minute of consecutive sounds can end up in a single frame of the specious present. Given this, it is also an account of the experience of succession. And, finally, it also resolves the phenomenological difficulty of characterizing the unity of consciousness over time.

But, even if we are with James this far, the theory faces a difficulty. Normal conscious experience does not present music that lasts for more than one frame of a specious present as a series of successive bows and sterns. On the contrary, conscious experience is continuous and seamless, no matter how long the melody.

One way to account for continuity on James' model is to posit a retention mechanism (Kelly 2005, p. 231). But this is a road straight to contructivism and its trappings. And while there are surely advantages to the hybrid approach, if retention can be invoked to explain continuity it might as well be invoked to explain succession, too, making the specious present theory redundant.

3.4 Barry Dainton

The problem of continuity of conscious experience that faces James' specious present view is addressed directly by an elaboration of that view offered by Barry Dainton (Dainton 2000). On this view, the experience of continuity is accounted for by a primitive non-transitive relation of co-consciousness, which holds between successive parts of any single specious present (Dainton 2008, p. 370; 2000, p. 176). What assures the continuity of the experience is the experience of the relation of co-consciousness that holds between the parts of any single specious present. On this view, specious presents partially overlap and result in a seamless stream.

For example, take consecutive conscious experiences Φ_1 and Φ_2, which both have two parts Ψ_1 and Ψ_2. On Dainton's view, Ψ_1 of Φ_2 and Ψ_2 of Φ_1 are actually one and part that can only be distinguished conceptually (look Figure 2).

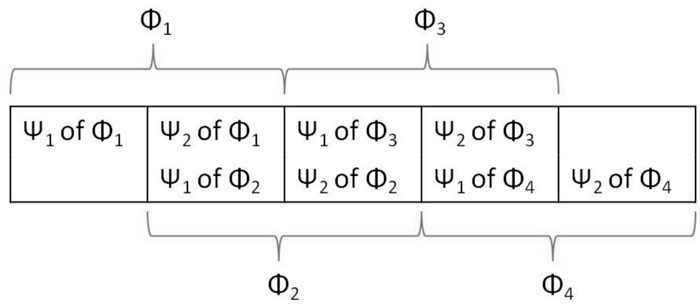


Figure 2. Barry Dainton's overlap model.

In Figure 2 above, successive experiences Φ1, Φ2, Φ3, and Φ4 each have two parts, represented by boxes. The boxes are doubly labeled in order to reflect their double-duty as parts of two distinct, but overlapping experiences. The result is a seamless and continuous stream of experience, in which conscious experiences have temporal extension. Just as on James' view, each conscious experience has a bow, and a stern, but the difference here is that the stern of one experience is also the stern of the one that succeeds it.

On Dainton's version of primitivism, just as on James', what explains the experience of succession is the temporal extension of the conscious experiences themselves. But, unlike James's view, Dainton's model presents a continuous flow of connected and temporally extended experiential parts, which form a unified whole in the way in which quantities of water form a river. Presumably, this answers Kelly's challenge that primitivism is unable to account for the apparent smooth continuity of conscious experience.

There is a problem for the overlap model. It seems to imply that parts $\Psi_1 \ldots \Psi_n$ of any experience Φ are experienced simultaneously. Since I will refer to this problem in subsequent discussion I will label it:

(PCE) Any experience of succession requires at least two successive experiences to be presented at one time

So, while $\Phi_1 \ldots \Phi_n$ might be experienced as successive and continuous, $\Psi_1 \ldots \Psi_n$ are not experienced as successive, but as simultaneous. This means that any given moment is crowded with all the parts of the specious present (Kelly 2005, p. 219; Gallagher 2003).

For example, let us say that the sequence of tones A, B, C is a part of a single temporally extended experience of succession of those tones, that is, an experience of a melody. But since A, B, and C are all parts of the same experience, not only are we presented with the succession of these tones but also with the chord A-B-C. This is phenomenologically implausible, and contradicts normal experience.

The crowding problem facing Dainton's overlap model, and presumably any specious present view that involves parts of experiences, is similar to the problem of duplication (PDE) that faces Husserl's view. On Husserl's view, the tone A, B, C could also be parts of a single experience of succession of those tones, but on account of their being in retention or protention. So in addition to the succession of tones A, B, C one would also experience the chord A-B-C, which is phenomenologically implausible, and contradicts normal experience.

While (PDE) and (PCE) are distinct theoretical problems, what they imply about experience is the same. The two difficulties (PDE) and (PCE) imply are problematic on account of the same phenomenological violation. They imply that conscious experiences appear differently than they actually do. The machinery that causes one to experience a chord instead of a melody is different for each model, but from the first-person point of view the result is indistinguishable.

Gallagher mounts essentially this very objection against Dainton's theory (Gallagher 2003). Given this similarity between the problems, it is perhaps not surprising that Dainton's answer to Gallagher, and (PCE) parallels the later Husserl's answer to (PDE). Dainton argues that (PCE) is a problem only if we also accept the view that we are aware of the different parts of a conscious experience at the same time.

But, Dainton insists, the stream of consciousness is in itself conscious; we are not conscious of it (Dainton 2003; 2000, p. 180). On this view

> We should take the relationship [between experiences] to be a primitive experiential feature, a direct and unmediated relationship, one which cannot be analysed away or reduced to anything else, and one which does not in itself have distinct phenomenological features (by which I mean: we are not aware of coconsciousness as an additional experiential ingredient, we are simply aware of experiences occurring together) (Dainton 2003).

In defense of this view, Dainton urges that it is not "an act of desperation to describe a relationship as primitive or basic if that is what it is—and that is how co-consciousness seems, at least from the standpoint of phenomenology" (Dainton 2003).

So, on Dainton's view, parts of the stream are not experienced as simultaneous with each other because they "possess what we might term *phenomenal presence:* they possess the immediacy and vivacity that are characteristic of all phenomenal properties as and when they occur" (Dainton 2008, p. 371). Dainton takes phenomenal presence to be a primitive fact in need of no further explanation (Dainton 2000, p. 26).

The improved primitivist model as presented by Dainton comes with theoretical commitments that are not any different from those made by later Husserl's constructivism. On Dainton's view, experience of succession is at least in part constituted by the properties of experiences themselves. Dainton's commitment to (D) is problematic for the same reasons that Husserl's, as I will show after laying out the holist strategy of explaining the experience of succession in the next section.

4.1 Holism

Holism is probably best characterized as an ontological thesis about the nature of conscious experiences. According to holism there are no individual conscious experiences at all. Instead, there is a single and unified field of consciousness. We can talk about this field *as if* it was constituted by individual conscious experiences, but that is misleading as far as the essentially holist nature of consciousness.

Holism is the denial of atomism, which is the view that conscious experiences are distinct from each other. As such, holism appears naturally well-suited to explain the phenomenology of unity of consciousness over time, and the seeming continuity of conscious experiences that characterizes the stream of consciousness. The appearance of unity of consciousness is grounded in actual unity of consciousness at and over time.

4.2 Timothy Sprigge

According to Timothy Sprigge's holism, conscious experiences are the totality of features and contents that make up one's phenomenology at any given time. On this view, individual parts of experiences

> are in an important sense not real parts of the total experience, nor are any of its other components. This is because they lack an individual essence which could be specified or grasped without reference to the whole to which they belong (Sprigge 1983, p. 219).

On this view, consciously hearing music while also consciously looking at a computer screen involves only one conscious experience of music-computer screen. The individual conscious experiences of a computer or of music cannot be understood, on this view, without reference to the whole music-computer screen amalgam

Sprigge's holism makes no ontological distinction between individual conscious experiences at any given time. So atomism is rejected out of hand. Given this, the appearance of unity of consciousness at one time is a straightforward consequence of actual unity of conscious experiences at one time. And, similarly, the appearance of unity of consciousness over time is the result of a similar unity over time.

In a recent paper Barry Dainton has argued that Sprigge's holism is not only defensible, but also supported by a variety of cross-modal effects discussed in perceptual psychology (Dainton 2010). In ventriloquism, for example, the relative location of a doll's moving mouth alters how we hear the voice of the ventriloquist that is holding the doll. The influence of the auditory conscious experience impacts the quality of the visual conscious experience, suggesting that they are connected in consciousness.

Cross-modal interference of this kind leads Dainton to suppose that individual conscious experiences are bound by a primitive relation of co-consciousness into a larger totality of conscious experience. Dainton explains:

> Two contents that are experienced together are in *immediate phenomenal contact* (as we might put it) with one another. This contact is of a distinctively pervasive: a1 and v1 are not only experienced together, but every part of a1 (the auditory experiencing of a bell ringing) is co-conscious with every part of v1 (the visual experiencing of a tree) (Dainton 2010, p. 137).

Immediate phenomenal contact is to be understood as a primitive relation, which is not a content of any conscious experience, but rather a structural feature of all conscious experiences. Given that cross-modal effects can be understood as the result of different conscious contents being related in this way, Dainton concludes that phenomenal holism similar to Sprigge's is at least defensible (Dainton 2010, p. 138).

Whatever we make of this view, it is not immediately obvious why cross-modal effects should support phenomenal holism any more than any other view about conscious experience. We can understand the ventriloquism effect as the result of auditory processing being influenced by visual information prior to the occurrence of conscious experience. If this is right, then the ventriloquism effect is not the result of immediate phenomenal contact between auditory and visual contents, but of a process that involves no consciousness at all.

And we have at least one reason to take that interpretation over Dainton's. The relevant psychological literature itself treats cross-modal effects as insights into the mechanisms of perception, not consciousness. Following this literature, in Chapter 4 of this dissertation I argue that cross-modal effects support a particular view of temporal perception that is in fact incompatible with Sprigge's view.

Regardless, I take Dainton's defense of holism as a reason to assess Sprigge's view in light of the puzzle of experience of succession. Unfortunately, even if Sprigge's view is defensible in the way that Dainton suggests, it faces other, more serious difficulties. The most serious of these comes from Sprigge's views about what he takes to be related issues.

Sprigge's holism about conscious experience is foremost the result of his views about the nature of reality itself. On Sprigge's view, reality is entirely mental in nature, and each part of that reality is essentially connected to every other (Sprigge 2006, 1987; 1994, p. 78; 1983, Chapter 5, 6). The same holds true of conscious experiences, which are components of this reality just as anything else.

According to Sprigge, "the universe as it really is consists of innumerable moments of experience, each of which is eternally just there" (Sprigge 1992, p. 13). Past and future conscious experience exist eternally, and each of them "in themselves, and as they really are, present experiences of their own momentary egos" (Sprigge 1992, p. 11). This leads to the central difficulty for Sprigge's holism—if egos are as momentary as conscious experience, it is not clear how they could ever experience the passing of time.

In fact, on Sprigge's view, it does not really make sense to distinguish the past, future, and the present when it comes to conscious experience. Sprigge himself suggests that

> this present experience is a future event from the point of view of other events, which are as present as it is in their own being, and so is both future and present, future for other events and present for itself, it seems an unavoidable conclusion that events which from the point of view of this present ego are future, are also present realities from their own point of view. (…) Futurity and pastness must then pertain to events only from the point of view of other events while every event must *be present from its own point of view, and as it really is* (Sprigge 1992, p. 12; Sprigge's italics).

Mental time, on this view, is an illusion. Sprigge offers a picture of a completely mental universe on which each part of that universe is simultaneously an experiential past, present, and future.

Unsurprisingly, from the point of view of Sprigge's conception of reality, the problem of characterizing the phenomenology of the experience of succession is actually a pseudoproblem. So Sprigge tells us that

> there is an element of illusoriness in the feeling of transition, for it goes with a feeling that somehow past, present and future are radically different sorts of reality, whereas the truth is that presentness is eternally the true character of every event, and that each is eternally there in precisely its own locus in the whole temporal series (Sprigge 1992, p. 13).

Indeed, if everything is always there and experiencing itself as present, as the view suggests, the experience of the passing of time is impossible. Parts of the universe are themselves connected but never experienced as such.

But the original problem remains. We *do* have the feeling of transition from one moment to the next—so much is at least taken for granted in Sprigge's discussion. Even if that feeling is illusory, we need to know why we have it.

Sprigge's eternalism and absolute idealism, however, cannot answer that question. This is because, according to Sprigge, individual momentary conscious experiences have their own individual and momentary proprietary egos. So, on this view, the feeling of transition from one moment to the next, that is, the experience of succession, involves a single momentary ego, which is tied to a single momentary conscious experience of something *other* than succession.

That leaves the question of where we get the sense of transition from one moment to the next essentially unanswerable. So, whatever the merits of Sprigge's holism in context of cross-modal perceptual effects, the view does not have the resources to explain the sense of unity over time that accompanies normal conscious experience. While the ontology of holism promises to yield a holistic picture of phenomenology, Sprigge's version suggests quite the opposite, which disqualifies his view as a workable solution to the problem of the experience of succession.

4.3 Sydney Shoemaker

Sydney Shoemaker offers his own holist strategy of explaining the experience of succession in context of an argument he makes against atomist theories of consciousness. Shoemaker argues that the experience of a melody as a melody is possible *because* of the unity of consciousness over time:

> It is essential to the awareness of the melody as *that* melody (…) that one be aware of the relationship between the different notes (…). And this requires unity of consciousness—the co-consciousness of the experiences of the different notes (Shoemaker 2003, p. 65).

On this view, similarly to the primitivist views of James and Dainton, a succession of experiences forms a temporally extended unit bound by consciousness and it is this temporal extension that makes an experience of succession possible. Shoemaker thinks that “in such cases we have a temporally extended experience” (Shoemaker 2003, p. 65).

But, unlike the primitivists, Shoemaker thinks that to experience a melody one needs to “be aware of the relationship between the different notes,” which requires awareness of the relation between successive experiences. So, on Shoemaker’s view, an experience of a melody as a melody consists of the following components:

a) Successive experiences

b) Experience of the relation between the experiences in (a)

According to Shoemaker, experience of the relevant relation between successive experiences is possible because of the unity via co-consciousness that holds among experiences in (a).

Shoemaker thinks each experience in (a) is unified relative to the other in virtue of being “inferentially promiscuous relative to the others and each is available to participate with the others in the relational control of behavior” (Shoemaker 2003, p. 64). So, the co-conscious experiences in (a) are bound by accessibility relations. On this view, inferential relations are necessary for the experience of succession.

So, unlike Dainton and others that use the notion of co-consciousness, Shoemaker defines co-consciousness as a form of access, not a primitive phenomenal relation. So, while Shoemaker’s view resembles primitivism, it isn’t clearly committed to the view that experiences are themselves temporally extended, as is the case for Dainton and James. Shoemaker’s view is that experiences are mutually accessible and thereby form a single experiential unit.

But, echoing James’s argument against constructivism, Shoemaker thinks that temporally unextended atoms of experience are impossible (Shoemaker 2003, p. 67). Conscious experiences are temporally extended, on this view, which is one of the central tenets of primitivism. But successive experiences do not constitute an experience of succession in the way that the parts of an experience come to be parts of a specious present. On Shoemaker’s view, the experience of succession results from something else.

Unlike the primitivist Shoemaker thinks that experience of succession occurs when one’s conscious experience “is synchronically co-conscious with a memory of a continuous series of mental states that includes the earlier one” (Shoemaker 2003, p. 65). Shoemaker’s recourse to memory is clearly a constructivist element of the theory.

Given all this, it is probably safe to say that Shoemaker's view has both constructivist and primitivist aspects, but it is not merely a hybrid of the two. Arguably, Shoemaker's view is better characterized on its own terms, as consciousness holism, which is the view that the factors that go into making a particular mental state conscious are inextricably intertwined with what goes into making different states co-conscious.

First clearly holist component of Shoemaker's view is the rejection of the view that the apparent unity of consciousness is the result of a succession of states being the objects of a single state of awareness. Shoemaker instead thinks that

> Experiences are co-conscious not by virtue of the fact that they themselves are the objects of a single state of awareness, but by virtue of the fact that they are components of a single state of awareness whose objects are events perceived by the subject (Shoemaker 2003, p. 65).

On this view, the objects and events consciously perceived by the subject comprise a unified field of consciousness. This field is constituted by these conscious perceiving and not by a second-order state.

Secondly, Shoemaker's argues for his view, which he describes as consciousness holism, by exposing what he thinks is the theoretical poverty of consciousness atomism. Atomism is, according to Shoemaker, the view that mental states can be conscious independently of other mental states being conscious. If this was true, then, Shoemaker argues, a series of experiences of notes could not be co-conscious in a way that would result in one to have an experience of the melody.

Shoemaker thinks that atomism is incapable of explaining how we become conscious of a melody as a melody, because it doesn't allow for the sort of holist inferential relation needed to account for co-consciousness. Without that, Shoemaker argues, atomism cannot explain the experience of succession. And since we obviously have such experiences, holism turns out to be the only viable theory in town.

Unfortunately, Shoemaker's argument against the atomists is not very good. While inferential relations are important to the causal role of any mental state, it is hard to see how they could play the role Shoemaker's wants them to. For one, inferential relations are at least partly constitutive of the *functional* role that a mental state has in the overall mental economy. But the relevant functional role of a mental state, such as its inferential role, might be independent of whether that state is conscious.

Shoemaker thinks that conscious mental states are functionally distinguishable from unconscious mental states. On Shoemaker's view, "it is precisely when a mental state is conscious that it plays the causal role that is distinctive of that state" (Shoemaker 2003, p. 64). What this means is that conscious mental states are inferentially promiscuous in ways that they are not when they are unconscious. In this way, co-consciousness makes conscious states distinct from unconscious states.

Contrary to what Shoemaker thinks, however, mental states that are accessible for reasoning or control of behavior are often unconscious. It is not at all clear that consciousness itself has a distinct functional role (Rosenthal 2008). Or at least Shoemaker has to give us a reason to think that it does in this case.

As it stands, it seems that the burden of proof is on the person that attributes a special function to consciousness, and not the person that attributes none or little. For example, a belief that people cannot normally walk through walls informs their behavior and reasoning on a regular basis, but it seldom causes them to consciously infer that they cannot walk through a wall. People's beliefs about walls, while accessible for reasoning and control, are typically unconscious.

And if this is all true, accessibility relations might be irrelevant to the unity of consciousness. The only kind of unity that they ensure is inferential unity, or psychological unity, broadly construed as the unity that characterizes an individual mind or person. The unity of consciousness is a separate issue.

But even if Shoemaker is right about accessibility and the function of consciousness, perhaps because consciousness itself is a matter of accessibility as he suggests, his holism faces a difficulty in explaining the datum at hand, that is, the experience of succession. In short, on Shoemaker's view, the experience of succession requires two experiential components:

a) Successive experiences

b) Experience of the relation between the experiences in (a)

There seems to be no reason to reject (a) since an experience of succession without successive experiences seems impossible (Pelczar 2010, for a contrary view). There is, however, a good reason to be suspicious of (b).

This reason comes from the plausible claim that an experience of a relation between two things requires that one be aware of both relata. Shoemaker himself, in context of arguing against atomism, states that

> if at a certain time I perceive two things and perceive some relation between them, such as that one is larger than the other, my experiences of the two will be co-conscious (Shoemaker 2003, p. 60)

And there is some plausibility to this claim, since it is hard to make sense of how we can perceive a relation between two things without perceiving the two things themselves. The same insight generalizes to consciousness.

For example, if one is consciously experiencing the relation of attraction between a magnet and some iron chips, then one is undoubtedly also consciously experiencing the magnet and the chips. Or at least it is hard to imagine how we can do one without the other. If we just saw the chips move and but were not aware of the magnet, then we would be also not be aware of the relation of attraction between the magnet and the chips. From our point of view, the chips would seem to move by themselves.

Similarly, an experience of the relation between two conscious experiences requires that one is aware of both of these experiences. And if that is so, then any single experience of succession would include an experience of what is in the present and also of what has just occurred. The result would be the past experiences lingering in ones phenomenology as a relata of co-consciousness that makes the experience of succession possible.

Consider the following sequence of events. At time t1 person S has experience E. At time t2 person S has experience F. Also, at t2 S has an experience of succession from E and F. Since the experience of succession requires that S is aware of both relata of the succession (at least according to Shoemaker 2003, p. 60), at t2 S is aware of F and again of E.

This is a phenomenologically implausible consequence of duplication that I labeled above as (PDE). Instead of an experience of a melody, (PDE) implies an experience of a chord, and instead of an experience of an object moving there an experience of a trail. If Shoemaker cannot avoid (PDE) in some way, then we have a good reason to reject (b) and with it his account of the experience of succession.

Shoemaker's view does not straightforwardly imply (PDE).   As Shoemaker himself notes, the problem arises only if the experience of multiple mental states involves a separate mental act that binds them together. Shoemaker subscribes to the view that "experiences are co-conscious […] by virtue of the fact that they are components of a single state of awareness" (Shoemaker 2003, p. 65; my emphasis). There are no extra levels of awareness that then lead to duplication.

This leads right back to primitivism and the claim that the experience of succession is the result of the conscious experience itself being extended in time. According to Shoemaker, co-consciousness of notes involves the temporal extension of the components of a single state of awareness. On this view, under normal circumstances, two successive experiences are never experienced as simultaneous because they are distinct temporal parts of a single conscious bundle of mental states.

The co-consciousness relation that holds between parts of a single, temporally extended state of awareness is itself experienced, but not in virtue of being represented by another state, which would bring about (PDE), but simply in virtue of holding between the experiences. Co-consciousness, then, even though it is defined in terms of accessibility, is in fact a basic feature of conscious experience in need of no further analysis. And that is what leads us to (PDE).

With that, Shoemaker's view turns out to be committed to thesis (D), which states that what underlies the experience of succession is the temporal succession of conscious experiences. According to (D), the temporal order in which conscious experiences, or experiential parts, occur, determines the timing that one will be presented with. The stream of conscious appearances corresponds, on this view, to the steam of states that underlies them.

In this section 4, and the previous two sections 2 and 3 I argued that versions of constructivism, primitivism, and holism are committed to claim (D). Some of these views explicitly endorse (D), while some of them, such as Shoemaker's holism, are lead to (D) on account of other commitments. The following section explains why (D) is problematic and any theory of the experience of succession that endorses it should be rejected.

5.1 Color Phi

There is a class of perceptual illusions that involve filling-in between stimuli. One of these is beta movement, which is responsible for perceived motion in movies. Another is the cutanous rabbit illusion, in which tapping the arm at different places creates the sensation of motion.

Out of these, the most discussed in philosophy is the color phi illusion, which occurs when one sees a still colored dot for some time, followed by nothing, then followed by a differently colored dot offset from the location of the first dot. Just as with beta movement, if the timing is right, people typically report seeing a single dot moving. What makes the color phi illusion especially interesting is that the moving dot changes color in the middle of that motion, seemingly before it is ever perceived in its final state.

What is puzzling about color phi is that whatever interpolation the brain is doing, it seems to involve looking into the future. The color of the moving dot seems to change before the onset of the second dot. The actual timing of the occurrence of the second dot seems to outrun the timing presented in conscious experience.

Daniel Dennett and Marcel Kinsbourne have argued that the only way to find color phi puzzling is to assume what they call the Cartesian theatre view of consciousness (Dennett and Kinsbourne 1992). On this view, consciousness is a spotlight that shines down on representations of the world and we are the audience looking at the show. The timing of occurrence under the spotlight of our consciousness determines the timing that we experience them as having.

Given this, it is no surprise that the color phi phenomenon is puzzling. If one assumes that the timing of the experience of the dots determines the experienced timing of the dot then it mysterious how an experience of changing color can occur before the onset of the next colored dot. The color changes before the spotlight ever reaches the next thing to come on the stage.

The color phi phenomenon is not an idiosyncratic anomaly—filling in occurs in all modalities, and in various circumstances. As already mentioned, filling in occurs in the cutanous rabbit illusion, which involves touch (Flach and Haggard 2006; Geldard and Sherrick 1972). And in audition the filling in effect occurs in the continuity illusion (Husain et al. 2005).

The continuity illusion and the other related phenomena are similar to the color phi phenomenon, in that they all involve filling in between two stimuli. And if that filling in also involves change in one of the features of the stimuli, then the result will be a situation in which conscious experience seems to look into the future. For example, if the continuity illusion also involves a change in pitch, then it will seem that conscious experience somehow predicted in which direction to start changing the pitch of the filled in tone before the second actually occurs.

Philosophers that are committed to the Cartesian theatre are committed to explaining these phenomena in terms of the properties of the succession of mental states that are responsible for them. But, as in color phi, we can construct two competing hypothesis about what is going in cases of auditory filling in—the Orwellian and Stalinesque—and not have any way of deciding which is correct. This is because the report is a result of first-person appearance of an interpolated tone where a noise should be. First-person appearance gives no way to decide which of the two hypotheses is true.

And if one were to find a way to probe the person that undergoes the continuity illusion to check whether they had two experiences or one that leads to the same problem. There will be no way of deciding whether the elicited report is the result of their interpolating an experience they just forgot, as the Orwellian hypothesis predicts, or whether they never had it to begin with, as is predicted by the Stalinesque hypothesis.

On the Orwellian hypothesis, the noise interrupting a tone starts a process that causes an experience that is immediately forgotten. On the Stalinesque hypothesis, the noise starts a process that never makes it into consciousness. On both hypotheses, when the listener becomes conscious of the second tone, or the continuation of speech, continuity between them is interpolated by the perceptual mechanism and renders the experience of the tone, or speech, uninterrupted.

The moral to be drawn from Dennett and Kinsbourne's discussion is that the Cartesian theatre view is wrongheaded. The experienced timing of events cannot correspond to the timing of the mental states that underlie that experience. The better hypothesis is the one that Dennett and Kinsbourne argue for, namely, that what does bear on the nature of experience is how it is represented.

In short, the moral of Dennett and Kinsbourne's discussion of temporal illusions is that we should reject (D) and adopt a representationalist conception of consciousness. On the representationalist conception of consciousness the experience of succession is explained in terms of representation. I labeled this thesis above as:

(R) Experience of succession is the result of mental states representing succession

and its generalized version:

(R*) Conscious experience is determined by the representational properties of mental states

Philosophers committed to (R*) have different views about the nature of the representational properties of experience, which I cannot adequately discuss here.

What is important about (R) and (R*) from the point of view of the present work is that the endorsement of either of these theses amounts to a rejection thesis (D). The constructivist, primitivist, and holist theories of the experience of succession that up committed to (D) cannot also adopt (R) or (R*), which means they cannot yield an explanation of temporal anomalies associated with filling in effects. Instead, we should follow Dennett and Kinsbourne and adopt a representationalist conception of consciousness.

A representationalist conception of consciousness is a form of atomism. Arguably, any view that adopts (R) or (R*) ends up being atomist. Conscious experiences, on this view, are atomic snapshots realized by representational properties of mental states.

As Shoemaker notes, represenationalist atomism is prima facie incompatible with the phenomenology of unity over time. This phenomenology involves a continuous and seamless stream of consciousness, which appears to have temporal extension. Given this, most of the theories of the experience of succession discussed above can be understood to be attempts to reconcile that phenomenology with the view that conscious experiences are distinct from each other.

So, if we accept (R) or (R*) then we are back where we started, namely, with the datum of apparent unity of consciousness over time, but with an atomist conception of conscious experiences that seems incompatible with it. This is not a problem for Dennett own theory of consciousness, on which consciousness itself is fundamentally fragmented.[4] The apparent unity of consciousness, on that view, is an illusion.

On Dennett's view, consciousness is very much like the light, which we see whenever we open the refrigerator door—it seems to always be on. Similarly, consciousness always seems to be there because we only notice it when we are aware of it. We simply assume that it conscious experiences are always going on, just as we might assume with the refrigerator light is always on.

[4] Dennett's take on the unity of consciousness is discussed in more detail in Chapter 1 and 5 of this dissertation.

So, if Dennett and Kinsbourne are right, then the apparent stream of consciousness is yet another type of refrigerator light illusion. A succession of conscious experiences going “on” and “off” appears to be unified over time because we are never aware of the “off” gaps in between the “on” of consciousness. And since only conscious experiences inform our phenomenology, we conclude that they are all seamlessly connected, as in a stream.

All of this might suggest that Shoemaker was simply wrong in thinking that an atomist theory of consciousness cannot account for the stream of consciousness phenomenology. Insofar as we go along with Dennett, which is not something that all representationalist atomists might want to do, this might be true. But there is a problem with Dennett’s view, which should give us pause.

5.2 Representationalism without First Person Operationalism

Dennett and Kinsbourne’s claim that there are no facts that can settle between the Orwellian and Stalinesque hypotheses is the result of their commitment to the view that experiential appearance is experiential reality. On this view, which I will call First Person Operationalism from now on, a subject’s reports about how things seem is the final word on how things are in the subject’s experience (Dennett 1991, p. 81, 96).

Even if First Person Operatationalism is coherent, which is not at all obvious (Schwitzgebel 2007), there are two independent reasons to think that it is mistaken. The first is the existence of conscious states on which we cannot report. The second is the existence of criteria for detecting consciousness that are independent of reports (Rosenthal 2005, p. 241-3).

During a regular day, we might have sensations and thought of which we are not aware of, and therefore cannot report on. Take as an example the daydreaming during a morning commute. After a few minutes of this, someone might bump into us, snapping us out of the daydream, and thereby making us aware that we have been thinking about something for some time.

I take it that it is entirely uncontroversial that sometimes people become aware of such trains of thought after they have been happening for a time. But a question arises as to what exactly has been happening up until that point. Were we aware that we were having a daydream before we were snapped out of it? Or was it unconscious?

There is a sense in which the thoughts that composed our train of thought were conscious. They were conscious in the same sense in which the experiences that comprise the periphery of our visual field might be conscious. From the first-person point of view, peripheral visual experiences seem to be of colored things, albeit somewhat hard to characterize. And the same is true of the thoughts we had during the daydream.

Normally, we cannot accurately report on the hazy colors and smeared objects in our periphery. As Dennett observes, if one were to put a playing card in the periphery of our visual field, we could report whether it is a Jack or a Queen, but not whether it is a red or black suit (Dennett 2001, p. 982; 1991, p. 54). Of course, it seems to us that our peripheral experiences involve color, and we are aware of them in that way, but it turns out that we cannot report on these colors at all.

The daydream on the commute is very similar. While we were daydreaming, we were aware of our train of thought in a rather minimal way, even though we were not aware of what we were thinking about at the time it was happening. Once we snap out of a daydream, we have to try to come back to the train of thought from memory to get back to it, albeit we have the sense that we what we were just experiencing was a part of our conscious life—just as we might think of the color of a card on the periphery of our visual field before we try to report on it.

It makes perfect sense to think that there are many thoughts and sensations of which we are conscious in this very minimal way, as it makes a great deal of things easier. As Rosenthal points out, “like any other mental construct, our first-person view of ourselves leaves out much detail, enabling us to concentrate on the big picture” (Rosenthal 2005, p. 237). If every aspect of our conscious experiences was present in vivid detail, the computational load would be immense, and we would likely have a hard time sifting through it all to get to what matters to us most.

But that does not mean that we do not have vividly characterized conscious experiences at all. When we focus on something, or when we learn how to discriminate between the qualities of our experience, our conscious experiences become more vivid. Presumably, this is what happens when snap out of a daydream.

In a relevant example, Rosenthal points out how the character of our conscious experience of wine can change with acquisition of an ability to discriminate between its various qualities. Sommeliers and lay connoisseurs of wine are thought to be able to experience things in wine regular folks cannot—or at least they say they do. But everyone that tastes the wines they do has some conscious sensations, albeit in a seemingly more coarse way.

When a non-expert has a sip of wine and then hears an expert describe the wine in various ways, this usually changes the way in which the non-expert consciously experiences the next sip. When this happens the wine itself does not suddenly change, and, presumably, the sensations of the wine are not different either—the chemical compounds in the wine that the sensory system responds to have not become different. What changed, however, is the way in which the non-expert is now aware of the sensation of the wine.

Under the influence of a particular description, non-experts learn to make new discriminations about wine. Similar stories can be told about discerning instruments in an orchestra, or colors in a painting. Describing a conscious experience in some way lets us have a reference point that we can use to compare it to other mental states of a similar type.

Rosenthal urges that all of this suggests that we can be conscious of the same sensation in various ways. The way that we are aware of a mental state makes a difference to conscious appearance, and all there is to appearance is our awareness, but there is also an underlying reality to the mental state itself. This is why we can be aware of it in a variety of ways, some of which will characterize it in more detail than others, or with more accuracy than others.

This in turn shows that Dennett goes too far in treating the objects of consciousness as merely notional appearances (Rosenthal 2005, p. 241). In order to be the objects of awareness that characterizes them in a variety of ways, sensations and thought have to be real entities, which can be individuated by the representational properties they instantiate. The underlying reality of these states might but need not be reflected in the way they are characterized by awareness, but when it is so reflected, it facilitates discriminations, as in the wine tasting example.

Making room for a reality/appearance distinction in consciousness is not yet sufficient to make a distinction between the Orwellian and Stalinesque hypotheses. Reports about conscious experience will not settle which of these obtains, even if there is an underlying reality as to what happened. They will deliver the same characterization of the conscious experience.

If these arguments are correct there is a fact of the matter about whether the color phi phenomenon involves a single conscious experience of a moving dot or two distinct conscious experiences of a moving dot. And we could appeal to this fact to uncover the real sequence of events and settle between the Stalinist and Orwellian hypotheses. So, in order to distinguish the Orwellian and Stalinesque hypotheses, we need a criterion for consciousness that is independent of subjective reports.

As of this date (December 2012), subjective reports are the gold standard for getting at conscious experience. There are promising alternatives, such as widespread brain activity, recurrent loops in neural activation, and certain kinds of EEG signatures (Seth, Baars, and Edelman 2005; Seth 2009; Todd 2009). If one of these could be the marker of conscious experience, then we would have a way to settle the Stalinesque-Orwellian impasse.

But, even if we cannot find an independent criterion, ultimately this does not bear on Rosenthal's thesis that we could distinguish between the cases in principle. The content of consciousness will be the same in both cases, with roughly the content: “there’s a single moving sensation that changes color” (Rosenthal 2005, p. 241). And this content will be the result of the way in which the sensation is represented, no matter which of the hypotheses turns out to be true.

Rosenthal’s view is incompatible with Dennett’s claim that the reality and appearance of consciousness are indistinct. This allows for an explanation of how it is that we better our ability to discriminate between mental qualities. Rosenthal’s view is compatible, however, with Dennett’s claim that the way that our awareness represents our experiences exhausts how they appear to us. According to Rosenthal, conscious appearance is completely determined by the way that our awareness characterizes the mental states it is about. In other words, Rosenthal’s theory adopts (R), which is the claim that conscious experience can be explained in terms of representation.

5.3 Towards a Representationalist Account

With all this in mind, if we accept Rosenthal’s atomist view, we will be in a good position to resolve the puzzles of the phenomenology of unity of consciousness over time. Given its compatibility with (R) it can yield an explanation of unity very much like Dennett’s refrigerator light account. On this view, the stream of consciousness is an illusion generated by us not being aware of the gaps in between our experiences.

Furthermore, Rosenthal’s view will not generate paradoxical consequences or lead to the implausible claim (D), as the views discussed in previous section typically do. Finally, just as Dennett’s view, it can also account for temporal illusions, and all without the problematic commitment to First Person Operationalism. But there is a remaining problem.

While the refrigerator light account might be sufficient to account for the experience of continuity between our conscious experiences, it is not, on its own, sufficient to account for the experience of succession. As James famously points out, a mere succession of conscious experiences is not sufficient to explain why these experiences appear to be more than just a mere succession (James 1890, p. 629). We also need to account for the temporal horizon through which our conscious experiences appear to be passing.

What lies behind the Jamesian dictum is the observation that conscious experiences appear to be a part of a stream, which itself has a temporal extension. The stream view can account for this sense of temporality by pointing out that conscious experiences are imbued with the past and extend on a temporal horizon simply in virtue of being parts of the stream. But nothing in the representationalist theory of unity—at least as far as I laid it out so far—has made sense of that.

It does not help to say that an experience of succession is simply a matter of having the sense that the present experience succeeds the one before it. The conscious experiences we just had change, in some sense, the ones that come after them. But while this is true, it is also not helpful to suppose that past conscious experiences change the content of the present conscious experiences or lingers on like a ghostly apparition. The conscious experience of a C on the end of a phrase A-B-C played on a flute has the distinct quality of being a C.

This is the crux of the puzzle of the experience of the passing of time, or temporality, as it is sometimes called. On the one hand, the conscious experience of the C is a part of an experience of a melody. On the other, it is just of a C. How it is that a single conscious experience can play this double role without the difficulties I discussed above is the main task of representationalist theory of temporal experience I will present in the next two chapters of this dissertation.

CHAPTER 3: Time Perception across the Senses

1 Mental Time

In the previous chapter I presented a number of philosophical theories about the experience of the passing of time. Some of those theories end up committed to the view that the experience of succession is in some way the result of the underlying succession of conscious mental states. I argued that all theories committed to this claim are at a disadvantage.

The claim that the temporal succession of mental states explains the experience of succession precludes a satisfactory explanation of perceptual illusions of time. Since theories of experience that are based on representation explain perceptual illusions rather well, I concluded that an adequate theory of the experience of succession should be stated in terms of representation. Other theories I surveyed faced other complications, which also put them at a disadvantage relative to a representationalist account.

In this chapter I offer a model of temporal perception, from a representationalist perspective, broadly construed. In the first section I lay out some constraints on a theory of perception of time that arise out of a distinction between two aspects of temporal perception: timing and duration. Perception of timing and perception of duration need separate accounts, which are nonetheless closely connected.

The section after that concerns multi-modal perception. The survey of empirical literature on the topic suggests that temporal perception involves modality specific mechanisms. If this is true then temporal information is represented differently in each modality.

In the third section of this chapter I give a philosophical theory of temporal perception, which accommodates the abovementioned constraints. On this view, perception of time involves temporal qualities, which piggyback on other mental qualities, such as red* or sour*.[5] The view I offer lays the foundation for a theory of conscious experience of the passing of time, which I offer in the final chapter.

2.1 Timing and Duration: Close but Apart

Some temporal information concerns the timing of occurrence of a particular event. Timing information typically specifies the onset or offset of a stimulus or event and it is usually represented by a temporal marker such as "10 o'clock" or "ten minutes ago." The marker refers to a unique temporal location on what can best be characterized as a timeline.

Another type of temporal information concerns duration, which is a measure of time elapsed between two temporal locations. For example, between 10 o'clock and 11 o'clock, one hour elapses. Duration can be characterized as the distance between two markers on a timeline.

In conscious experience, timing and duration are closely related. Take as an example a conscious experience of a 1 second red flash, followed by a 1 second pause, followed by a 1 second red flash. An accurate subjective report on the duration of the

[5] To make things easier, I am using a star to designate a mental quality as opposed to a perceptible property. So, a P* is in my mind while P is out in the world.

pause would state that it was 1 second long. But what goes wrong if the report states that the pause was half a second?

There are at least two possible explanations. The observer could have made an error in judging the *duration* of the pause as shorter than it was. But they could have also made an error in judging the *timing* of the onset or offset of either flash by half a second. And to the observer these cases are indistinguishable from the 1st person point of view, which highlights the close connection between timing and duration in conscious experience.

Even though there is a strong connection between timing and duration in conscious experience, there are cases where timing and duration are clearly dissociated. For example, most people can attest that time flies when they are engaged in something they enjoy, and it drags on when what they are doing is boring. In such cases, duration judgments are usually distorted while judgments of timing are accurate. So we can subjectively judge the onset and offset of a stimulus accurately, but still get its duration wrong behaviorally.

Timing and duration can also be dissociated experimentally. For example, a flood of dopamine distorts judgments of duration (Rubia et al. 2009; Wearden 2008), but it does not distort judgments of timing (Rammsayer 1997). Also, a moving stimulus is perceived to endure longer than a stationary one without affecting reaction times to onset and offset of the stimulus (Kaneko and Murakami 2009). The dopamine effect and the motion effect suggest that the mental processes that underlie subjective timing and duration are distinct.

There are also cases that point in the other direction. Damage to basal ganglia and cerebellum impairs the timing of movements that involve fine motor control or stimulus (Nichelli, Alway, and Grafman 1996) as well as judgments of durations under 1 second (Malapani et al. 1998). This suggests a close relationship between the mechanisms that underlie subjective judgments of timing and subjective judgments of duration. But whether these judgments are determined by distinct mechanisms or by changing operation of the same mechanism—an issue I will address later—does not affect the main point of the present discussion. Mental representation of time has two distinct but closely related aspects: duration and timing.

This leads to an important constraint on a successful theory of mental time. First, as mentioned above, it is sometimes impossible to tell whether one is getting the duration of a stimulus or its timing wrong, and vice versa. A successful theory of mental time will explain why this is so. We need to explain why timing and duration are so closely related.

Secondly, we need to explain how subjective judgments of duration and subjective judgments of timing can come apart, as in cases when time flies or drags on. It would be ideal if it would also not conflict or otherwise undermine the account of the close connection between subjective duration and subjective timing from the first constraint. This explanation should also be such as to be easily extended to similar effects from the empirical literature.

2.2 Neural Mechanisms Underlying Visual Perception of Timing

We know that the mechanisms responsible for processing the timing of stimuli have a consistent sampling rate. For humans, this rate is approximately 30 milliseconds for vision (Pöppel 1997, p. 57). Distinct visual stimuli need to be separated by at least 30 milliseconds and when they are presented within this 30 millisecond window they are perceived to be simultaneous.

There is evidence that there is a second timing mechanism that operates with a 3 second sampling window, which is independent of the one operating at 30 milliseconds. Ambiguous stimuli such as the necker cube alternate their perceptual interpretation approximately every 3 seconds (von Steinbüchel, Wittmann, and Pöppel 1996). Similarly, sequences of phonemes such as CU-BA-CU alternate between the CUBA interpretation and BACU interpretation approximately every 3 seconds (Pöppel 1994). The 3 second sampling rate can be found in a number of other studies of perception in all modalities, which all suggest that every 3 seconds "the brain asks: "what is new?'" in the perceptual input (Pöppel 1997, p. 59).

What this suggests is that the sensory system takes snapshots at a constant rate and looks for changes between successive ones. When a difference is detected, the system either decides to assume the change signals a new stimulus or a change in an existing one. Either way, this involves the sensory system processing timing, that is, the onset of change in the stimulus. When no change is detected, the system continues on whatever it was doing, effectively treating the stimulus as extended in time, that is, as having duration.

And there is some evidence that suggests which neural mechanisms do this. In one fMRI study, participants were asked to watch several uncut movies of everyday activities such as making a bed (Zacks et al. 2001). Each movie was shown three times. During the first presentation, the participants were asked to simply pay attention. In the next two, the participants were asked to segment the movies into events that were meaningful to them, and to press a button to mark the beginning of one event and the end of another. In the second viewing, they were asked to segment in a coarse-grained way. In the third viewing, they were asked to segment finely.

The fMRI recordings taken during active segmentation showed significant activation in areas V5 (MT) and FEF. V5 (MT) is an area of the visual system which is involved in processing motion and FEF is the part of the motor cortex that controls voluntary eye movement. When time-locked to the active segmentation times, the results from the passive viewing showed similar activation. This shows that the brain tracks temporal event structure in virtue of a purely visual mechanism, which is sensitive to the timing of the onset and offset of a stimulus.

Activation in V5 (MT) and FEF was strongest during the coarse-grained segmentation, and weakest during the passive viewing. This suggests that bottom-up information about the stimulus is modulated by top-down influence from processes that keep track of the segmentation of a visual scene into events. Based on this analysis, the authors conclude that processing temporal breaks in events is a mix of top-down and bottom-up processes.

Importantly, these results constrain what can count as a plausible theory of mental time. As one of the commentators on these results noted:

> The fact that [V5/]MT tended to be active at points that were later labeled as event boundaries indicates that the event boundaries in the stimuli were

registered in the brain independent of any outside motivation to do so (Tong 2001).

This means that temporal boundaries are sensed even when the observer is not aware of it. I come back to the issue of perception of time without awareness in the next chapter.

For now, what is important is that the just mentioned studies inform us about the neural mechanisms involved in the sensation of timing. Temporal breaks in a series of events can be characterized as temporal markers similar to those that mark the onset and offset a simple stimulus such as a red dot. So the detection of temporal boundaries enables one to sense the onset and offset of a stimulus.

The role of early visual areas V1 and V5 (MT) in the detection of temporal boundaries implies that timing discriminations depend on modality-specific processing. And this conclusion can be generalized to other modalities. Audition and touch have neural structures that are functionally analogous to V1 and V5 (MT). So we can expect that other modalities feature mechanisms that are dedicated to detecting temporal boundaries and with them the onset and offset of a stimulus.

2.3 Neural Mechanisms Underlying Visual Perception of Duration

The detection of temporal boundaries does not exhaust the involvement of early sensory areas in temporal sensation. Evidence for further involvement comes from effects such as phi movement, flicker completion, or the cutaneous rabbit, among others. In all of these effects, two or more distinct stimuli are treated by the sensory system as if they were the temporal boundaries of one stimulus. The result is a single percept with an extended duration.

In all of these effects, the temporal distance between successive stimuli is critical. When the distance is set right, almost everyone reports seeing a change from two stimuli to a single stimulus. The two stimuli are perceived as one stimulus with a longer duration.

In one fMRI study of the apparent motion effect, which lies behind apparent motion we observe in movies, the early visual area V1 was shown to respond equally during apparent motion and when the stimuli were not fused. But area V5 (MT) was shown to be more active during apparent motion (Muckli et al. 2005; Muckli et al. 2002). This suggests that V5 (MT) is involved in filling-in between temporal boundaries created by a pair of stimuli. Unfortunately, a correlation is not enough to get at the role that V5 (MT) has in that filling-in.

To explore the role that V5 (MT) plays in the effect, V5 (MT) activation would have to not only be correlated with the effect, but also shown to be its cause. This was the aim of another fMRI based study, which used activation patterns in apparent motion effects to model connections between V1 and V5 (MT) (Sterzer, Haynes, and Rees 2006). The prediction in that study was that activity in the connections between V5 (MT) and V1 could be correlated with the filling-in of individual parts of an illusory curve created in V1 by apparent motion. And as predicted, the model that best fit the data had no lateral connections in V1, but lots of feedback from V5 (MT). The authors conclude that V5 (MT) has a robust role in filling-in between temporal boundaries, while V1 does not.

The aforementioned apparent motion studies strongly suggest that V5 (MT) is crucial to the sensation of timing and the sensation of duration. On the one hand, as the passive movie watching study shows, V5 (MT) is responsible for encoding temporal boundaries, which specify timing. On the other hand, as the apparent motion study shows, V5 (MT) is also responsible for filling-in between these temporal boundaries, which extends duration.

However, it is probably important to note at this point that V5 (MT) is not usually discussed in connection with temporal sensation. V5 (MT) is usually brought up in context of motion sensation (Zeki 2004). And there are good reasons to do so. People that do not have V5 (MT) are unable to perform routine tasks that require them to keep track of changing or moving objects (Zeki 1991). Such people can still sense motions that are relatively slow, but any fast motion is invisible to them. So when they pour a cup of coffee, for example, what they see is a cup that is empty, than the same cup half filled, and finally the same cup spilled over.

This debilitating disorder can be temporarily induced by shutting down V5 (MT) with transcranial magnetic stimulation (TMS) (Walsh et al. 1998; Beckers and Zeki 1995). The result is a temporary inability to perceive motion for fast-moving stimuli. Since V5 (MT) plays an important role in the detection of temporal boundaries, then TMS to this area would presumably disturb perception of timing as well—being unable to detect the onset and offset of an event, as in the start or end of a pour of coffee.

But, supporting the view that V5 (MT) is also involved in filling-in between temporal boundaries, repetitive TMS to V5 (MT) also reduces the apparent motion effect (Matsuyoshi et al. 2007). Without the fill-in between onset and offset, a single event becomes two isolated events or no event at all. Seeing a snapshot of a still coffee pour without change over time is seeing no temporal change. This suggests that visual detection of duration is impaired without V5 (MT).

The existence of modality-specific neural mechanisms such as V1 and V5 (MT) underlying temporal boundary detection, and filling-in supports the view that perception of time at least in part depends on modality-specific mechanism. These results support the view that processing and representation of temporal information is carried out independently by each modality. This point places an important constraint on a successful theory of temporal perception: a theory of mental time has to be able to account for modality-specific temporal processing and representation.

Also, almost all the studies mentioned in this section assume processing temporal information about events can occur unconsciously. Some of the discussion of these results explicitly endorses this claim (Tong 2001, quoted above). But there is also independent evidence from blindsight that supports the view that the V5 (MT) can operate without the involvement of consciousness.

Blindsight is a rare condition in which people with damage early visual areas of the cortex—V1 in particular—perform above chance in visual discrimination tasks, but report having no conscious visual experience at all. As such, blindsight is a robust example of sensation without awareness. And it turns out that motion detection is to some extent preserved in blindsight that results from severe damage to V1 as well.

In one study, a blindsighted participant was presented with the line motion illusion, in which a fully drawn line or rectangle appear to be painted from one side to the other, when preceded by an appropriately located visual stimulus (Azzopardi and

Hock 2011). In the first experiment of the study, a square visual stimulus was followed by a rectangle stimulus, which extended upwards or downwards from the location of the square. Normally, such a stimulus results in a motion aftereffect in which the rectangle appears to be drawn away from the location of the square.

This stimulus was presented in the blidsighter's blind visual field, and the participant was then asked to discriminate whether the rectangle extended upward or downward by pressing one of two buttons. And, strikingly, the participant discriminated the direction of apparent motion significantly above chance, even though he reported no conscious awareness of motion. This shows that even without any input from V1, and without any awareness, the blindsighter was able to discriminate motion.

In the second experiment of the study, the same participant was asked to perform a similar discrimination, but on a different stimulus. In this case, the rectangle that followed the initial square stimulus was black, and the background was an intermediate grey. Normally, this pair of stimuli generates apparent motion in the opposite direction; the rectangle appears painted toward the initial stimulus, as opposed to away from the initial stimulus, as in the standard line motion illusion.

When this stimulus was presented to the blindsighter, however, his discriminations did not conform to what is normally perceived. In this case, the blindsighter reported the direction of apparent motion to be away from the initial square stimulus, seemingly ignoring the influence of color and shape. This shows that motion detection does noy depend exclusively on input from earlier visual areas such as V1, which process shape and color. The blindsighters performance supports the view that other areas such as the superior colliculus transmit visual information directly to V5

(MT). This conclusion comports with other evidence such as a recent study on macaque monkeys in which direct stimulation of the superior colliculus was shown to cause activation in V5 (MT) (Berman and Wurtz 2011, 2010).

To sum up, the empirical evidence presented in the last two subsections strongly supports the view that we can sense both timing and duration unconsciously. The studies cited above give us a good idea how the sensory system does this. First, visual mechanisms responsible for the sensation of timing depend on the detection of temporal boundaries. The early visual area V1 is critical to this process.

Secondly, the visual mechanism responsible for the sensation of duration depends on filling in between temporal boundaries. The early visual area V5 (MT) is critical to that process. And V1 and V5 (MT) can process temporal information without the involvement of any awareness, which supports the view that temporal perception can occur unconsciously. The modality-specific mechanisms involved in this process support the view that temporal processing is modality specific.

3 Multi-modal Perception of Timing and Duration

There are several reasons to think that each sensory modality processes and represents temporal information separately and differently. One comes from the fact that information from one modality can affect how information is processed and represented in another modality, but not the other way around. Vision, for example, is normally dominant over audition and audition is rarely dominant over vision when it comes to spatial perception (Bertelson 1999). If all sensory mechanisms processed spatial information in the same way, there would be no such asymmetry—all spatial information would be treated the same and have equal importance.

Asymmetrical dominance is especially pronounced in the spatial ventriloquism illusion, in which a puppet appears to be talking, while the puppeteer that is actually talking appears silent. The ventriloquism illusion depends on conflicting inputs about the location of the source of speech. On the one hand, the observer receives auditory input that correctly specifies the source as the puppeteer. On the other hand, the observer receives visual input that incorrectly specifies the source as the puppet's moving mouth. If the puppeteer's mouth is close enough to the puppet's mouth, and the puppeteer's mouth is not very salient, then the visual input will trump the auditory input and the location of the source of speech will be represented as closer to the puppet than it actually is. Ventriloquism works because vision usually dominates audition in spatial perception.

The situation is reversed with time; audition usually dominates vision in temporal perception. This is demonstrated in the temporal ventriloquism effect, in which the timing of visual stimuli can be changed by auditory input, but not vice-versa (Bertelson and Aschersleben 2003). In one temporal ventriloquism study participants were asked to synchronize finger taps with visual pacing flashes that are paired with tones (Aschersleben and Bertelson 2003). In the first experiment, the participants' taps were consistently biased toward the tone, if the tone occurred before or after the pacing flash.

But in the second experiment of the study, when participants were asked to synchronize their taps with auditory pacing tones paired with offset flashes, their taps were only weakly biased towards the flash. The auditory distractor changed the tapping rate, when it was paced by flashes. But the visual distractor did not significantly change the tapping rate, when it was paced by tones.

So audition biases rhythmic taps paced by vision, but vision does not equally bias taps paced by audition. This shows that audition dominates vision in the perception of timing. And this asymmetry suggests that the way that timing of a single event is perceived is determined by information from audition more than information from vision. That in turn strongly suggests that time is processed differently across those modalities.

The dominance of audition over vision in the temporal dimension can also be demonstrated using an experimental paradigm designed by Benjamin Libet and colleagues (Libet et al. 1983). In Libet's paradigm a disc rotates clockwise around a path of twelve equidistant positions, completing a full revolution in 600ms. The movement of the disc is interrupted by a flash at random times, and then participants are asked to report the timing of occurrence of the flash relative to one of the twelve positions of the disc.

In the altered Libet paradigm, a click is presented either slightly before, slightly after, or simultaneously with the rotating disc's appearance at one of the twelve positions around its path (Fendrich and Corballis 2001). If the click precedes the disc coming into one of its twelve positions, participants report the timing of occurrence of the flash relative to one of the twelve positions of the disc as earlier than it was. If the click comes after the disc, then they report the timing of the flash as later. The effect shows that timing of the auditory stimulus influences the perceived timing of the visual stimulus.

But, as with the other temporal ventriloquism study, there is no effect in the other direction. When the clicks are presented at a constant rate, but the flashes are offset to be either slightly before or slightly after the clicks, only a small effect or no effect occurs. In this case, participants normally report the timing of the occurrence of the clicks accurately. This experiment demonstrates the dominance that audition has over vision in determining subjective timing of a multisensory event. And it further supports the view that temporal information is processed differently by different modalities.

When two identical visual targets move across a screen and cross paths, they are usually perceived to pass through each other (Bertenthal, Banton, and Bradbury 1993). However, when a sound is presented at or around the time that the targets cross, the targets are usually perceived to bounce off each other (Sekuler, Sekuler, and Lau 1997). Since it is the simultaneity of the cross-over and the tone that is crucial perceive bouncing, this an example of cross-modal dominance in the temporal dimension of perception. And, as in the previously mentioned effects, here audition also dominates vision in the perception of timing.

The dominance of audition over vision in the temporal dimension can even result in completely illusory stimuli. For example, when a flash is accompanied by more than one beep, the flash is perceived to occur twice (Shams, Kamitani, and Shimojo 2000). Again, this effect shows that mental representation of timing is very strongly influenced by audition—to the point that it can result in illusory stimuli.

In the case of multi-modal perception of duration the direction of dominance is different. Visual information can, to some extent, affect auditory perception of duration, but auditory information does not affect visual perception of duration to the same extent.

Overall, vision is dominant over audition when it comes to perception of duration, which is the reverse of the perception of timing.

In one study on multi-modal perception of duration, participants were presented with a stream of steady (not looming) stimuli is interrupted by a looming stimulus (disk increasing in size or upward frequency-modulated sweep) in the same modality (Van Wassenhove et al. 2008). The reports of the participants indicate a subjective dilation of the duration of the looming stimulus—the looming stimulus is consistently judged to be longer than it is. And when a series of looming stimuli is interrupted by a steady stimulus, the steady stimulus is judged to be of shorter duration than it is. This holds for visual and visual-auditory stimuli equally.

But if a series of looming visual or visual-auditory stimuli is interrupted by a steady auditory stimulus, no subjective time dilation occurs for the auditory stimulus (Van Wassenhove et al. 2008, p. 4). So while looming auditory streams affect visual stimuli, looming visual and visual-auditory streams do not affect auditory stimuli. This indicates that duration distortions do not transfer from vision to audition all the time.

Similar asymmetry occurs when the presented series is composed of steady visual stimuli paired with steady auditory stimuli. The duration of an oddball looming auditory stimulus presented after such a series is accurate (New and Scholl 2009). This indicates that visual information blocks the auditory dilation effect that would occur if the steady stream were composed of only auditory stimuli.

Finally, when steady visual stimuli are paired with looming auditory stimuli in a stream, the judged duration of the oddball steady auditory-visual stimulus is not compressed. Again, no dilation occurs because of the influence of information about duration of the event coming in from vision. The asymmetry demonstrates the dominance of vision over audition in perception of duration.

The above discussion gives further support to the claim that duration processing is modality specific. This and similar dominance effects in timing perception are, arguably, the result of the calibration and integration that needs to occur between modalities. So we have to assume then that at some point duration information is represented separately in each modality, and it is the interaction of the various modalities that results in the final perception of duration.

But the interaction between different signals from individual sensory mechanisms is not the most fundamental time-related problem of multi-sensory perception. The crucial difficulty the sensory system faces lies in the physical differences between the stimuli and the sensory organs that detect them. Light travels faster than sound, for example, and requires more processing capacity. And the sense of touch depends on the transmission of signal from variously spaced nerve endings; sensory signal that starts in the foot has a larger distance to travel than a signal started in the nose. So the central issue is not how to integrate the disparate signals, but which ones.

Multi-sensory integration of temporal information has been studied extensively, but little is yet known about the mechanisms that underlie it (Vroomen and Keetels 2010, for review). What seems clear is that the brain compensates for cross-modal differences by treating some signals as originating in a single source. Presumably, this assumption drives the operation of a modality-neutral mechanism that takes information from distinct modalities and integrates them into a final temporal percept.

In one study concerned with this phenomenon, participants were presented with audio-visual pairs with a delay between them (Kopinska and Harris 2004). They were then asked to press one of two buttons to indicate whether the sound or the light occurred first. Analysis of the button presses reaction times shows that simultaneous audio-visual pairs are perceived as being simultaneous despite differences in the time it takes the signal to get from its source to the sense organ. The effect is simultaneity constancy.

As with other types of perceptual constancy, simultaneity constancy allows us to perceive things as constant even across large variations in incoming signal. Color constancy, for example, allows us to perceive a green wall as being the same color, even though what we actually see is a large number of different shades of green. There is a certain window beyond which differences are too pronounced not to be noticed as when the shades of green on the wall are in too much contrast with each other. This can happen when the wall is illuminated by a spotlight, for example. In similar way, two simultaneously occurring stimuli will be perceived as temporally distinct when the two signals reach the perceiver at too great a distance apart (Dixon and Spitz 1980).

Simultaneity constancy is commonplace. It manifests itself, for example, in our perceiving a batter striking a baseball as a single audio-visual event. Our brain expects it be a single event so it appears to us to be a single event. And this happens even though the auditory signal and the visual signal reach us at different times, and are processed by different sensory systems. Of course, when we sit in the top row of the stadium, we experience a pronounced disconnect between sound of the bat hitting the ball and what we see down below, but that happens only when the distance from the batter is substantial.

Simultaneity constancy also encompasses touch. In one study, participants were first presented with visual and tactile stimuli and then asked to respond as quickly as possible by pressing a button (Harrar and Harris 2005). Their reaction times to visual stimuli were constant, but reactions to tactile stimuli were slower the further away the stimulus was from the brain. The obtained results allowed the experimenters to create a function, which could then be used to predict the temporal window in which differently located visual and tactile stimuli are perceived as simultaneous.

In the second experiment of that study, the participants were presented with pairs of variously offset (0-200 milliseconds) visual-visual and visual-tactile stimuli located on different parts of their body. They were then asked to press one of two buttons to indicate which of the two stimuli came first. The results were then compared with the data collected in the first experiment.

The participants' reaction times to visual-visual pairs presented at different body parts resulted in same reaction times and the same point of simultaneity, as those predicted in the first experiment. Tactile-tactile pairs presented at different body parts resulted in a different pattern of reaction times, also as predicted by experiment one. However, the point at which two tactile stimuli would be perceived as simultaneous was different from the first experiment.

Pairs of visual-tactile stimuli presented at different body parts did not differ from the prediction at all. But pairs of visual-tactile stimuli presented to the same body part did not match predicted simultaneity from the same experiment. This result indicates that the mechanism coordinating visual and tactile timing compensates for processing time to maintain simultaneity constancy. This effect is especially pronounced for multi-sensory pairs presented in the same place as if they were one event.

In the third experiment the participants were exposed to 5 minute trains of light/sound pairs with a 250 millisecond interval between them. As a consequence, their reaction times shifted in such a way as to move the point of simultaneity by 40 milliseconds. The sound needed to be presented 40 milliseconds earlier to achieve the same point of simultaneity that was obtained in the first experiment.

The participants were then shown visual-tactile pairs. And, strikingly, there was no shift in their subjective judgments of simultaneity for the touch/light pairs. This shows that the timing shift caused by visual-tactile pairs does not affect perceived timing of tactile stimuli.

The fact that the adaptation affects simultaneity constancy for one pair of modalities, but not another is significant. The effect strongly suggests that simultaneity constancy for touch and vision is the result of a mechanism that is distinct from the one that handles simultaneity constancy for audition and vision. So the third experiment of this study, together with other studies to the same effect, gives further support to the view that time is processed differently by distinct modalities (Harrar and Harris 2008; Hanson, Heron, and Whitaker 2008).

Multi-modal perception leads to a number of effects that indicates a couple of things. First, as already mentioned above, temporal information is represented at some point in the perceptual processing hierarchy of each sensory modality. Second, this information is then integrated into a sort of final draft of the event that specifies its timing and duration.

The second conclusion is strongly suggested by the variety of non-symmetric cross-modal effects. Especially those in which temporal information from one modality plays a more important role in determining the way that temporal information is eventually represented. These effects are possible only on the assumption that temporal information is first represented at the level of a single modality, and then plays a role in determining the content of another modality neutral representation. Finally, all of this shows that a theory of mental time that does not allow for modality-specific representations of timing and duration is incompatible with overwhelming empirical evidence to the contrary.

3.1 Mental Qualities

So far nothing has been said about how time is represented by mental states. The dominant view in philosophy is that mental states represent by instantiating various representational properties. It is widely noted that intentional states such as thoughts have intentional content, which can be captured in a clause that follows a mental verb and "that." For example, the sentence "Pam thinks that the opera is longer than usual" is ostensibly about Pam's thought, which has the content <the opera is longer than usual>.

Pam's thought has the content <the opera is longer than usual> in virtue of instantiating properties that enable it to represent that the opera is longer than usual. And the representational properties of Pam's thought are in some ways similar to the representational properties of the sentence “The opera is longer than usual.” On account of this, we can say that intentional states such as beliefs and thoughts represent in a sentence-like way. But whatever representational properties are responsible for Pam’s thought being about an opera are not the same as the representational properties that are responsible for Pam’s sensations being of an opera.

My motivation for urging that sensations and thoughts represent differently is that, unlike the content of intentional states, the qualities of sensations cannot be captured in a clause that follows a mental verb and “that.” Unlike the intentional content of thoughts, what sensations are <u>of</u> can be captured by a compound singular term following a mental verb term as in “Pam hears the sound of singing.” We can therefore suppose that qualitative states such as sensations of operas represent in virtue of the representational properties they instantiate being in some relevant sense term-like.

The claim that the sensations represent in a term-like way is somewhat metaphorical. It does not amount to the claim that sensations represent linguistically. Sensations represent in a term-like way merely in that they are do not have an internal structure that may be construed as following rules such as grammar or syntax. Each term represents on its own, simply in virtue of the relationship it bears to something else.

This last point aims to be expository and neutral about what terms are, that is, whether they are definite descriptions or rigid designators. I am making it here merely to highlight the contrast between sensations and intentional states, the latter of which represent in virtue of their representational properties being in some relevant sense sentence-like. Even if terms are sentence-like, as some philosophers tend to think, that does not change the fact that terms appear to function differently than sentences in context of propositional attitude ascriptions.

So, to sum up the distinction, intentional states such as thoughts represent in virtue of instantiating properties that realize intentional content. And states such as sensations represent in virtue of instantiating mental qualities. Nonetheless, they both represent, albeit only thoughts do so in virtue of intentionality. I will assume this to be true for the remainder of the present discussion.

It is important to note that the view sketched above is not the only one available and, arguably, it is not very popular at this time. There is significant controversy about how to characterize the difference between thoughts and sensations and whether there even is any. One popular theory is representationalim, which is the view that conscious sensations are similar to intentional states. On this view, representation is always intentional, even if it is a property of sensations.

On Gilbert Harman's version of representationalism we are only aware of mental states with respect to their intentional properties (Harman 1990). Michael Tye and Alex Byrne have different views, but their versions of representationalism aim at essentially the same thing—the elimination of the distinction between qualitative and intentional properties (Byrne 2001; Tye 2002). The important assumption of these views is that, similarly to thoughts, sensations represent in virtue of instantiating intentional properties.

There are also other views. However, in the interest of parsimony I will assume that the distinction between the properties that realize intentional content and the properties that realize qualitative character is a good one. And, arguably, nothing that I will say in the following depends on it. So from now on I will simply assume that there are two distinct ways in which mental states represent. The standard understanding of intentionality will do for thoughts. The way that sensations represent, however, is a little more complicated.

The first complication comes from the observation that the role of mental qualities is not so much to represent sensible properties as to enable the organism to respond to various environmental situations. Most importantly, qualitative states allow organisms to be conscious of objects in their environment and respond differentially to them. Arguably, the representational aspect of qualities enables an organism to respond in that way.

On this view, mental qualities are the properties of qualitative states that are typically instantiated when an organism perceives a perceptible property. They also determine the way in which the organism is conscious of what it senses. And mental qualities also determine the role that the qualitative state will play in the mental economy of the organism.

Importantly, mental qualities resemble and differ from each other in various ways—mental red is more similar to mental orange than to mental blue, for example. And these similarities and differences form distance metrics that reflect how many discriminations the organism can make between any two perceptible properties. The metrics form spaces of relations occupied by modality-specific mental qualities (Rosenthal 2005, p. 204).

The resulting quality spaces are homomorphic to similarly defined spaces of perceptible properties.[6] This should not be surprising, given that mental qualities are normally instantiated when an organism discerns a perceptible property in its environment. The taxonomy we use to differentiate between perceptible properties is thereby easily applied to mental qualities, because of the perceptual role that mental qualities play in our mental life.

On Rosenthal's view of mental qualities, a mental quality featured in a sensory state is defined by its position in a space of qualities that is characteristic of the sensory modality in question. Mental red, for example, is defined by the relations that it bears to other visual mental qualities such as mental orange, mental blue, and differently saturated mental red. The resulting three-dimensional quality space defines the mental qualities for vision.

Similarly defined quality spaces specify mental qualities for other sensory modalities. And in addition to seeing colors, hearing sounds, smelling smells, and so on, we also sense more complex properties such as shape, location. It is possible that the quality space modal can even be extended to perception of faces, which involves several dimensions that can be used to define similarity and difference metrics (Oosterhof and Todorov 2008).

3.2 Spatial Mental qualities

Quality space theory has already been extended to explain sensation of spatial

[6] A homomorphism is a function that maps one set onto another, preserving some features of the original set. For groups, "a *homomorphism f* from a group G to a group K is a function f: G→K such that f(e) = e' if e and e' are identities in G and K respectively and for all g, g'∈G, f(gg') = f(g)f(g') (Mendelson 1990, pp. 102.)

properties (Rosenthal 2005, p. 198-9, 220-2; Meehan 2002, p. 638-40; 2007). The various shapes are similar and different to each other along several dimensions, such as size and the number of discernable sides. For example, triangles are more like squares than like circles, and big squares are more like big circles than like small triangles.

The similarities and differences between various shapes define a space of relations in which any perceivable shape can be located. In order to enable an organism to make perceptual discriminations between spatial properties, the sensations involved have to represent spatial properties in a way that is sensitive to the relevant similarities and differences between them. So visual shape qualities are similar and different to each other in the same way in which visible shape properties are similar and different to each other. And the result is a set of mental qualities that forms a space of relations similar to the space of perceptible shape properties.

The resulting shape quality space is homomorphic to the space of relations between perceptible shapes. And the homomorphism allows an organism to make discriminations among shapes. Whenever the organism instantiates qualitative states that are similar and different to other qualitative states in the same way in which corresponding shapes are similar and different, they are perceptually discriminating these shapes.

Perceived shapes always bound more basic properties such as color. This intuitive observation leads George Berkeley to famously argue that

> For my own part, I see evidently that it is not in my power to frame an idea of a body extended and moved, but I must withal give it some colour or other sensible

quality which is acknowledged to exist only in the mind (Berkeley 1998/1685, Part 1, §10, p. 106).

Berkeley observes that we see colors as bounded by shapes and where a particular perceived color ends, a shape ends with it.

Berkeley's phenomenological observation also has empirical support in a variety of Gestalt phenomena such as the watercolor illusion (Pinna 2005), the Kanizsa triangle (Frisby and Clatworthy 1975), and the neon color spreading effect (Bressan et al. 1997). In the neon spreading effect, for example, introducing colored boundary information causes one to perceive color where there is none, showing the close connection between perception of color boundaries and colored shapes.

Let us assume then that in vision the boundaries between mental colors can define mental shapes. On this view, the boundaries of mental shapes end where one mental color ends and another begins. In this way, the shape qualities piggyback on the more basic qualities such as mental colors.

And we sense space in other sensory modalities in a similar way. We hear the spatial aspect of sounds because we can discern the location of their source in ambient space that is otherwise devoid of sound. And we feel tactilely the shape of objects because of we discern where textures begin and end. Smells can be sensed as having a spatial dimension as well, even though this ability is relatively minimal in humans (Hubert et al. 1980). Other animals, such as dogs, presumably have a very fine-grained metric for the spatial dimension of smell.

In general, only when an organism discerns the boundaries of where one perceptible property ends and another begins will it discern spatial properties of the perceived object. In that way, perception of shapes depends on perception of more basic properties. Spatial mental qualities are instantiated only when more basic modality-specific mental qualities are instantiated as well.

3.3 Temporal Mental Qualities

Similarly to the way that spatial boundaries of basic perceptible properties allow organisms to sense shapes, temporal boundaries of such properties allow them to sense the timing of a perceivable event. And the similarities and differences between these timing properties define a space of relations within which perceptible temporal properties are located. Among these are the properties such as timing and duration—the properties about which we make temporal judgments.

Whatever we make of that way of thinking about mental qualities, perceiving a melody played on a flute involves making auditory discriminations of each of the sounds produced by the flute. And when such discriminations are made, each of the sounds is heard as such. The auditory qualities instantiated at that point—whatever they are—will determine the way in which we perceive the flute sounds.

One reason to think that it is the mental qualities that determine how we perceive the sounds, as opposed to just the sounds themselves, is that we sometimes misperceive. We could, for example, hear a C-sharp instead of a C. In this case, even though a C is being played, we discriminate a C-sharp and instantiate an auditory quality that typically corresponds to a C-sharp.

When we hear a sequence of notes, such as the A-B-C melody played on a flute, something else happens in addition to the auditory discrimination. We also discriminate changes from A to B and from B to C. Without such discriminations we would hear the A as lasting throughout the time that we should have heard the B and C.

One might doubt that change requires sensory perception distinct from the perception of sounds and colors, and so on. But there is a good reason to think that indeed change is a distinct feature of perception. We can sometimes fail to make a discrimination of change, while still perceiving sounds and colors, and so on. In vision, when we are distracted by a mud splash on the screen, a blink, or a saccade this leads to temporary change-blindness (Simons and Levin 1998; Rensink, O'Regan, and Clark 1997; Simons and Levin 1997).

Sometimes, the changes that are obscured by the distractor can be quite large and perceivers report seeing no change at all. Nonetheless, when people are forced to guess what they perform significantly above change, suggesting that we can perceive things even without being aware of the change (Fernandez-Duque and Thornton 2000). This suggests that change is a distinct aspect of perception, of which we can sometime be unaware. We sometimes fail to discriminate change or misperceive it, just as we might fail to discriminate perceptible properties, such as colors and sounds.

However, change discriminations are different from discriminations of colors or sounds in that they depend on detection of onset and offset of those perceptible properties. When we detect onset of a sound we discriminate an auditory change. Similarly, when we detect a change in color we discriminate a color boundary or a change in color.

We can think of change discriminations as depending on discriminations of other perceptible properties. For example, when the mental quality of a flute B* is followed by a C* we typically make an auditory discrimination of change—and this is even when no such change occurred in the environment. However, when no new quality is instantiated after the B* no change is detected, either. It is hard to imagine what it would mean for one to discriminate an auditory change without a corresponding difference in auditory qualities.

Change discriminations also underlie our perception of time. As William James pointed out, “awareness of *change* is thus the condition on which our perception of time's flow depends” (James 1890). This is because, invariably, in the world we inhabit, the offset of a property comes after its onset. There can be no offset of a flute A without prior onset of that A. And the onset of the A comes after the offset of silence, or some other auditory quality or qualities.

When an A is followed by a B, one has to discriminate the offset of the A as temporally prior to the onset of the B. And when we hear the A, we hear it as coming after some silence, or some other auditory qualities. Given this, the mental qualities that enable us to detect the offset and onset of particular properties must typically themselves reflect the temporal relations in the environment.

Typically, these temporal qualities bear the same relations (‘before’ and ‘after’) to each other as the perceptible properties in the environment. Empirical evidence amply supports this view (Klincewicz 2011). So, to perceive the onset of a flute C is to discriminate an auditory change, which involves one thing happening after another. Without a similar relation in the qualities underlying our discriminations, change would never be detected. In general, if mental qualities were not temporally related in this way, succeeding in navigating one's environment would be very difficult.

On this view, temporal qualities that enable us to make temporal discriminations are instantiated whenever other mental qualities, such as red*, sour*, or a flute's C*, are instantiated. Again, temporal qualities are relational, in that they enable one to detect change only when there is a relevant before or after relation that holds between mental qualities. These relations reflect the before and after relations in the onset and offset of perceptible properties in the environment.

On this view, perceiving involves instantiating mental qualities such as color or sound. And when such qualities are instantiated, we also detect change. And when we detect change, we discriminate the onset or offset of some property in the environment. So, whenever we discriminate some property in the environment, we perceive it as related to its onset in our experience.

Before and after relations between mental qualities are sufficient to also explain how we perceive duration, that is, temporal extension. For each pair of onset and offset qualities, a single duration quality has to be instantiated as well. And we will always perceive duration if we perceive at all. For example, when we perceive a flute B, we also perceive it as related to its onset at some point in the past, however recent. And whenever we perceive something as related to its onset in this way, we will have two temporal qualities flanking a duration quality.

This is why, alongside the timing qualities that mark onset and offset, our perception always features duration qualities. For each note we hear in a melody—that is, for each auditory quality—there must be a corresponding pair of timing qualities.

These timing qualities flank a single duration quality that results in us perceiving something as extended in time. The duration qualities make it possible for us to perceive melodies, among other things, as extended in time. This is the gist of the temporal quality model that explains how we can perceive temporal extension.

On this view, the ability to make timing discriminations depends on an ability to detect temporal boundaries of more basic perceptible properties such as color and sound. This is because timing properties are nothing but the temporal boundaries of other more basic perceptible properties such as colors and sounds. The onset of a red stimulus marks a time at, say, t=0, which is closer to the offset of red t=2 than to its offset at t=3 and further from t=6 than from t=4.

The onset of a perceptible property at t=0 will bear relations “before” and “after” to an array of other timing properties. These relations define a one-dimensional space of similarities and differences between the detectable timing properties within a particular modality. Just as on a number line, where every number bears one of these relations to every other number on the line, the timing of a particular perceptible property is related to all the others.

And just as with other perceptible properties, any perceptible timing property has a corresponding mental quality, which plays the relevant role in both representing timing and influencing the organism’s mental economy. So a temporal quality corresponding to the onset of the stimulus at t=0, will represent it as closer in time to t=2 than to t=3 and further from t=6 than from t=4. This particular timing quality will be similar and different to other timing qualities in ways that parallel the similarities and differences between the perceptible timing properties.

Paralleling the structure of the space of relations that define perceptible timing properties, the mental temporal quality space is one-dimensional. The temporal quality space has the structure of a number line, which naturally incorporates "before" and "after" relations that hold between the timing of perceptible events. This homomorphism between the one dimensional temporal quality space and the one dimensional structure of time enables the organism to make the relevant timing discriminations.

As an aside, the reader should note that the numbers I used in the examples of perceptible timing properties and corresponding timing qualities are strictly metaphorical. For a variety reasons, it is very unlikely that timing is mentally represented by numbers. Most importantly, our brain works in analog.

It is equally implausible that temporal reality is numbered in any such way. Numbers are just a convenient way of representing the relations that hold between temporal boundaries, which are nothing over the relative temporal distance between onset and offset of more basic properties. The world is analog, after all.

As mentioned in the beginning of this section, timing is not all there is to temporal perception. In addition to sensing the timing of a stimulus, an organism can also sense it as enduring for a period of time. And the temporal quality space model I offer has a ready view about that.

Importantly, we do not need to add a new dimension to the one-dimensional temporal quality space to accommodate duration. Duration qualities, just as duration properties, are reflected in the relations that hold between individual timings. On the temporal quality space model, when we sense a red dot appear at t=1 and disappear at t=3 two visual timing qualities are involved—one for each of the temporal boundaries of the event. And the two mental timing qualities that correspond to t=1 and t=3 constitute the temporal mental boundaries of the occurrence of the more basic mental qualities.

Consequently, the two timing qualities also carry information about the duration of the red dot stimulus, just as subtracting the value of t=1 from t=3 is sufficient to represent real time duration of the event (as 2 seconds, for example). In turn, the relations between mental timings define mental durations and thereby also other relations such as “longer than” and “shorter than,” which are the relations that hold between sums of temporal distances. The one-dimensional temporal quality space is sufficient to enable an organism to represent and respond differentially to both timing and duration—there is no need for an extra dimension or quality space for duration.

Nonetheless, discriminations of duration are possible only when the temporal mental qualities are available and the temporal distance between them is filled in with sufficiently similar mental qualities. When the qualities change, that will mark a new temporal boundary. A red dot on an equally red background is undetectable both with respect to its shape and timing of its onset and offset. Consequently, its duration is undetectable as well.

On the temporal quality space model, timing qualities define the boundaries of duration qualities. And similarly to the way that the boundaries of colors define shape, temporal mental qualities corresponding to perceived timing define durations. Durations are also similar and different from each other. Durations of one hour and more like duration of hour and ten minutes than durations of 5 seconds.

The distance between the discriminable durations defines a metric. A number of such metrics in turn defines a space of similarities and differences. This space specifies all the discriminations an organism can make in a particular modality. Humans, for example, can normally distinguish two sounds as distinct when they are at least 50 milliseconds apart (Pastor et al. 2006). When the two sounds are less than 3 milliseconds apart, people consistently report perceiving one sound instead of two. The similarity and difference space for sounds reflects this. So, possible small differences across individuals aside, these durations reflect the distances between individual temporal qualities in the temporal quality space.

Just as in the case of sensing space, the ability to sense time depends on an ability to sense more basic mental qualities such as color and sound. We need to be able to instantiate basic qualities in order to instantiate temporal boundaries. This means that each modality has its own quality space of temporal mental qualities that is independent of similar quality spaces in other modalities. As is the case with spatial qualities, temporal qualities are modality specific.

3.3.1. Temporal Mental Qualities and Underlying Neural Mechanisms

In an earlier section of this chapter I mentioned some empirical results that implicate the cerebellum and other areas in the processing of timing in the subsecond range. I mentioned that area V5 (MT) and V1 of the visual system is involved in temporal boundary detection for events that are longer than a second. And that V5 (MT) is crucial in filling-in between these boundaries. I drew a conclusion from these results, which set constraints on a successful theory of the mental representation of time: temporal sensations can occur unconsciously and every modality processes time separately. Both of these constraints are satisfied by the temporal quality space view.

First, on the quality space model, all mental qualities, including the temporal qualities, are defined and individuated by the roles that they play in the mental life of an organism. So a mental quality's perceptual role is independent of the way that an organism is conscious of it. This means that temporal sensation can occur unconsciously.

On the temporal quality model, every modality has its proprietary resources for representing time. This is because the theory predicts that every modality will have its own temporal quality space. All temporal mental qualities piggyback on more basic mental qualities such as mental color and mental sound.

The result is that time is represented and discerned in virtue of modality-specific mental qualities. The ability to make temporal discriminations in one modality is distinct from the ability to make temporal discriminations in other modalities. Temporal information is processed differently in each modality and results in the instantiation of distinct temporal mental qualities. This is because temporal boundary detection in each modality depends on the operation of distinct neural mechanisms. The prediction of modality-specific quality spaces is not only compatible with, but vindicated by empirical results.

3.3.2. Temporal Mental Qualities and Cross-modal Effects

This claim that each modality has its own quality space is also supported by evidence from studies concerned with multi-modal perception. The asymmetrical dominance across modalities strongly suggests that at least at some point temporal processing is carried out by modality specific mechanisms. And this can be accounted for only on the assumption that timing and duration is represented distinctly in different modalities. Given that modality specific processing of time is predicted by the temporal quality space model, these results highlight its theoretical virtues.

The temporal quality space view also implies that there has to be a certain amount of coordination of temporal information from different modalities. Without such coordination the model would predict that simultaneity is perceived only in circumstances where the signals from different modalities are processed at the same time. But, as the simultaneity constancy literature shows, the signals do not have to be processed simultaneously for one to perceive a multi-modal percept as having a single source in time.

The different sensory timing mechanisms process and represent time differently, and result in diverging judgments. In one study, filled auditory durations are shown to be routinely judged as longer than filled visual durations of the same length (Goldstone and Goldfarb 1963). Some researchers that duplicated this effect speculate that it is caused by an internal clock that oscillates at different rates, depending on the modality (Wearden et al. 1998).

This is a prominent example of the differences between modalities when it comes to temporal judgment and might suggest a completely decentralized model. On this view, the sensory temporal mechanisms are modality specific and the temporal judgments are modality specific as well.

Data about temporal judgments equally supports a more centralized model, on which each modality has its own timing mechanism, and its own proprietary quality space, but there is also a further mechanism responsible for judgments. On this view, temporal information is passed on from a modality-specific mechanism to this other mechanism, which in turn integrates and coordinates them. The result of this process is a single perception that integrates and coordinates information from the modality-specific sensations. The content of the sensation is the basis for the judgment.

A perception of time is thereby distinguished from a sensation of time. Perceptions represent an event as having temporal properties. Sensations never represent anything as having any properties at all—they represent these properties by bearing the same similarities and differences to each other that hold between the properties themselves. As such, they cannot serve as the basis for temporal judgments, which are always judgments that something is the case.

In perception, events are not represented in the same way as they are represented in the various modalities. Sensations represent in a modality-specific way. Perceptions, on the other hand, represent a-modally via intentional content. So, on the temporal quality space model, temporal information is represented by mental qualities in each modality, but eventually this information is itself also represented as being a certain way by a perception. And the content of perceptions will be determined by the coordination and integration of modality-specific information from sensations.

As a result of the various differences between modalities, judgments about the temporal dimension of events sometimes go awry. Such cases could be the result of the auditory timing mechanisms being more precise than the visual mechanism, for example. On the quality space model, such differences can be accounted for by the differences between the metrics of the modality specific quality spaces.

These considerations lead to one further point. While some of the temporal perception effects mentioned above might be the result of processing done by the mechanisms of sensation, some might not. Some temporal illusions might be the result of the operation of the mechanisms underlying integration and coordination. I will return to this point in the final chapter where I discuss consciousness.

CHAPTER 4: Time Perception without Awareness

1 Behavioral Performance and Conscious Experience

Subjective verbal reports are currently the most reliable way of getting at the contents of a person's conscious experience, even though there some researchers are hopeful about discovering better measures (Seth, Baars, and Edelman 2005; Seth et al. 2008). Such reports are elicited by direct questioning of the participant or by relying on questionnaires that are filled out after a trial or after a trial block. Subjective verbal reports about the temporal features are based on the participants' conscious experience of the duration, timing, and temporal order.

Objective performance, on the other hand, can be assessed by tracking eye movements to targets, by recordings from an electromyogram, or by changes in skin conductance. All types of recordings of physiological activity in the brain or the body other than self-directed behavior or verbal reports can be classified as an objective measure. Subjective and objective measures can sometimes come apart, even in the temporal domain.

Unfortunately, the psychophysical and imaging experiments used as evidence in studies of time perception often rely on paradigms that rely on participants' subjective verbal reports about the duration, timing, and temporal order of presented stimuli (Grondin 2010). Some of these studies are offered as support for the so-called dedicated models, which posit a clocking mechanism or mechanisms located in specialized parts in the human brain (Wearden 2008; Treisman et al. 1990; Gibbon 1977; Treisman 1963). But there are also distributed models, which posit brain-wide mechanisms, such as aggregate energy levels in populations of neurons (Eagleman and Pariyadath 2009; Pariyadath and Eagleman 2007).

It is not obvious that time perception is connected to the mechanisms of conscious experience of time in a way that would make subjective verbal reports bear on the neurobiological models in the way that those studies suggest. We already know that perception can occur without conscious experience. There are many examples of this, such as induced blindsight, which involves participants reporting that they have guessed even though their discriminations of a visual target are significantly above chance, priming, and subliminal perception (Kouider and Dehaene 2007; Lau and Passingham 2006; Breitmeyer, Ro, and Singhal 2004; Marcel 1983).

The main hypothesis of the discussion below is that a distinction between performance and participants' subjective reports can be demonstrated in the case of time perception. Giving credence to such a distinction would support one of the predictions of the temporal quality space model outlined in Chapter 3, namely, that perception of time can occur without awareness. This is the main goal of this chapter.

The first two sections review some existing evidence for the claim that time perception can occur without awareness. It should be noted that that discussion mainly concerns the visual modality, but the results reported can generalize to other modalities. Perception without awareness has been observed in other modalities, such as audition (Lamy, Mudrik, and Deouell 2008; Skoe and Kraus 2010), olfaction (Stevenson 2009), touch (Pritchett, Gallace, and Spence 2011), and even proprioception, if we treat it as a distinct sensory modality (Masters, Maxwell, and Eves 2009; Fridland 2011)

After reviewing the evidence for perception of time without awareness, the next two sections present a report of a psychophysical that I carried out in the Action and Perception Lab in City College of New York with guidance from Dr. Tony Ro. The aim of those experiments was to understand the mechanisms that underlie a disturbance in normal perception of time caused by a looming visual stimulus, which is on collision course with the face. The results show that conscious experience of time can be manipulated by changing features of the looming stimulus. I close the chapter with a discussion of how this evidence bears on the temporal quality space theory developed in chapter 3.

2.1 Subjective Judgments of Timing

Strong support for the claim that the content of subjective judgments of timing is determined by unconscious processes lies in electroencephalogram (EEG) recordings. Such recordings are useful in studying the unfolding of electrical activity in the brain over time. By averaging a series of EEG recordings over a large number of trials, the experimenter can get a good idea of the temporal order of electrical activity in the brain associated with a particular task.

In a series of EEG experiments Benjamin Libet and colleagues showed that the earliest cortical responses to a tactile stimulus occur approximately 30 milliseconds after the onset of the stimulus. This initial activity is followed by a progressive ramping up of electrical activity in the motor cortex, which is usually referred to as primary evoked potentials (Libet 2002; Libet et al. 1979). Primary evoked potentials in the motor cortex carry on for approximately 500 milliseconds before a conscious sensation of a tactile stimulus.

Subjective reports Libet collected from participants in his experiments show that conscious sensations present the timing of the occurrence of a tactile stimulus as being 500 milliseconds earlier than the conscious sensation itself. In other words, the timing of the occurrence of the conscious sensation is projected backward in time up to 500 milliseconds. This mechanism seems to compensate for the 500 milliseconds of processing time evidenced by the EEG recordings of primary evoked potentials. Consequently, the 500 millisecond projection backward in time presents the timing of the stimulus near its actual occurrence.

Libet and colleagues also showed that direct electrical stimulation of the medial lemniscus, which is a set of nerve projections going through the brain stem to the thalamus, elicits primary evoked potentials in the primary motor cortex (Libet et al. 1979). If this stimulation is carried on for 500 milliseconds, a conscious tactile sensation occurs just as with a stimulus to the skin. And if the tactile stimulus and direct stimulation of the medial lemniscus occur simultaneously, the participant usually reports the two sensations to also be simultaneous (Libet et al. 1979). Both lemniscus stimulation and tactile stimulation results in primary evoked potentials and subjective backward referral in time.

And when the surface of the motor cortex is directly stimulated by electrical impulses it elicits a conscious sensation without associated primary evoked potentials. Strikingly, if direct cortical stimulation occurs simultaneously with stimulation of the medial lamniscus, or with skin stimulation, the sensation caused by the cortical stimulation appears to the participant to occur earlier than the others (Libet 2004, p. 76-8). This strongly supports the view that it is the onset of primary evoked potentials that correlates with the timing of the stimulus as it appears in conscious experience.

Libet argues that the mechanism that is responsible for the primary evoked potential recordings is critical to subjective backward referral in time (Libet 2002). This conclusion is supported by the results that show that direct stimulation of the motor cortex does not result in either primary evoked potential recorded or subjective referral. And, because the recorded brain events are not in any way conscious, this also shows that the way that timing is represented is at least in part determined by unconscious processes.

Similar primary evoked potential recordings have been made in the visual cortex (Roeber et al. 2008) and in the auditory cortex (Picton et al. 1974; Cone-Wesson and Wunderlich 2003). Presumably, whatever neural mechanisms are involved in subjective backward referral in other modalities also compensate for processing time between the onset of the stimulus and a conscious experience of the stimulus. Given all this we have to accept the assumption that the content of subjective judgments of timing is at least in part determined by unconscious mechanisms.

2.2 Subjective Judgments of Duration

Subjective backward referral in time supports the view that what matters to how we judge timing is how it is represented by mental states that are the eventual product of unconscious processing. But the timing of the onset and offset of a stimulus is only one of the temporal features of a stimulus we make judgments about. There is also duration.

There are several models of the psychological mechanisms that underlie duration judgments; I mentioned some in the introduction to this chapter. The traditional model posits an internal clocking device, which oscillates like a pendulum. On this model, each oscillation counts for a unit, which is then added to the value stored in a temporary buffer. The contents of the buffer at the offset of the stimulus determines the content of a duration judgment. At that point the buffer may be flushed or continue to accumulate units.

One widely accepted view is that there are several oscillators tied to different kinds of duration judgments. On this view, there are internal clocks that correspond to, roughly, the 24-hour day cycle, and which regulate the circadian rhythms associated with sleeping patterns and digestion (Moore-Ede, Sulzman, and Fuller 1982). There are also theories that posit clocks operating in the range of seconds (Wearden et al. 1998; Zakay and Block 1997; Church 1984; Treisman 1963), and milliseconds (Creelman 1962).

But few of these oscillator models posit an actual neural pendulum; the oscillations are just theoretical posits meant to explain a variety of temporal illusions. If the rate of oscillation or accumulation changes in between the onset and offset of a stimulus, the duration of the stimulus will be misrepresented. Similarly, if the magnitude of the unit that accumulates changes, or the contents of the buffer are distorted, the result will be misrepresentation of duration. Hence, the oscillator models can provide a powerful explanatory model of misjudgments of duration.

However, there is controversy about the mechanisms that underlie judgments of durations in the range of milliseconds. There are internal clock models for this range (Abel 1972; Creelman 1962). But some models posit mechanisms that track energy levels or aggregate behavior of large populations of neurons (Bueti and Walsh 2009; Eagleman and Pariyadath 2009; Karmarkar and Buonomano 2007; Mauk and Buonomano 2004). On these latter views, rapid change in energy levels can lead to distortions of duration in the subsecond range—an oscillator and a buffer are unnecessary.

There are independent reasons to believe that whichever theory is correct with respect to the mechanisms underlying duration perception, that mechanism is distinct from the mechanism responsible for conscious experience of duration. In one study, groups of manic, severely depressed, and normal people were asked to complete the trail-making test, which involves connecting 25 dots with a line (Bschor et al. 2004). This task measures motor-perceptual acuity as well as ability to attend and focus on a single motor-perceptual task. Both depressed and manic patients showed lower acuity on the trail-making task compared with the control group.

After completing the trail-making task, all groups were asked to make a judgment about how fast or slow time appeared to be passing and mark a place on a vertical 100 millimeter line to express their judgment. Marks above the middle meant a faster rate and marks below indicated a slower rate. As predicted, manic patients took time to be passing by faster than controls, who in turn estimated time to be passing by faster than depressives.

In the third task, all three groups were asked to produce time intervals by pressing a button. Pressing the button once flashed a picture of a light bulb on and off on a computer screen and pressing it again turned the light bulb off. The produced duration was supposed to be 7, 35, or 90 seconds.

Both the manic and depressed patients overestimated the longer durations producing shorter durations than required. And manic patients overestimated the 90 second durations significantly more than depressed patients. Both clinical groups, then, produced shorter durations than controls, even though they differed in their subjective reports about the rate of the passage of time.

Finally, these groups estimated the passage of time by pressing a button and producing as in the previous task. Here, the durations to reproduce were 8, 43, 109 seconds. There was also a 12 minute and 40 second video that the participants were asked to estimate verbally.

In the 109 second interval manic patients created a significantly longer duration with their button presses than depressed and healthy controls. All groups overestimated the duration of the video. However, the mean estimation of the video by manic patients was more than twice as long as the actual length of the movie and significantly longer than the other groups.

All of this points to dissociations between performance on temporal tasks and conscious experience of time. As evidenced by their reports with marks on a 100 millimeter line, depressed patients consciously experience time as slowed down, while manic patients consciously experience time as sped up, relative to controls. There is a clear difference between the subjective judgments of the three groups.

As far as objectively measurable performance, however, things did not line up with subjective reports. The depressed group and the manic group performed similarly on time estimation and production trials. Both estimated time to be passing by slower than the normal group—at least for longer durations—and estimated durations as shorter than they really were.

This suggests that the mechanisms of temporal perception cannot determine the content of subjective judgments. Manic and depressive patients perform similarly on tasks that require perception of time, but differ markedly in their subjective judgments about the rate of the passage of time. This kind of a result confirms the view that the contents of time perception and conscious experience of time can come apart.

Similar dissociations between subjective reports and performance have been observed in people under the influence of psilocybin, which is a hallucinogenic toxin found in various fungi (Wittmann, Carter, et al. 2007). In that study, it was observed that people under the influence of medium to high dosage of psilocybin scored very high on the “timelessness” and “oceanic boundlessness” scale for altered conscious experience. Surprisingly, their performance on tapping tasks and duration reproduction tasks did not suffer as much as their conscious experience.

In another study, which focused specifically on the distinction between verbal reports and performance on duration estimation, participants were presented with a blue box on a gray background for 400, 600, 800, 1000, 1200, 1400 or 1600 milliseconds (Lamotte, Izaute, and Droit-Volet 2012). Prior to the experiment, participants were asked to complete a questionnaire. They were asked to rate, from 1 (totally disagree) to 5 (totally agree), how much they agreed with the following statements: “when I am sad, I feel I am being slower," "when I drink coffee or tea, I find that the time goes faster" or "when I am in pain, I feel I am being slower" and "the more I focus attention on time, the slower time goes.'' Only the last statement was relevant to this study, but the rest were included to hide the purpose of the study.

The experiment had two conditions. One was the single task condition, in which the rectangle was presented alone and participants had to estimate the duration of the rectangle. In the dual-task condition, a series of digits was presented in the center of the rectangle. The participants were asked to estimate the duration of the rectangle while simultaneously reading the digits aloud backwards.

The number of digits in the rectangle increased as a function of the stimulus duration. There were 2 digits for the 400, 600 and 800 millisecond durations, 3 for 1000 and 1200 milliseconds, and 4 for 1400 and 1600 milliseconds. Each number in the digit series was randomly chosen between 1 and 9 from one trial to another trial.

Perhaps unsurprisingly (Zakay 1989), the results showed that, except for the two shortest durations (400 and 600 milliseconds) durations of the rectangle were significantly underestimated in the dual task condition, relative to the single task condition. Strikingly, however, there was a positive correlation between a participant's score on the item of interest in the questionnaire and accuracy in estimating duration for both conditions. The more participants agreed with the statement that focusing attention causes the slowing down of subjective time, the better they were at estimating duration of the blue rectangle. Similar but statistically smaller correlations were found for other items in the questionnaire.

These results show that awareness of the effects of attention on subjective time distortion caused participants to be better at estimating subjective duration. However, this awareness did not cause the duration distortion to go away completely. This suggests is that the perceptual mechanisms responsible for the duration distortion are not only thing affecting how we consciously experience time.

The right conclusion to draw from these results, and the others cited above, is that at least two distinct mechanisms are involved in subjective judgments of duration and performance on duration tasks. This means that the mechanism relevant to performance does determine the content of the judgments. This means that the contents of subjective judgments about duration are not determined by our perception of duration. When it comes to duration, performance and conscious experience can come apart.

Importantly, similar dissociations between performance and conscious experience of time are possible in other perceptual illusions of duration. For example, when a stimulus appears to occur earlier than it actually does because of an attractor stimulus from a different modality, as is the case in temporal ventriloquism, there is a possibility that the elicited judgment gives us insight into the participant's conscious experience without shedding any light on what is going on with them perceptually (Aschersleben and Bertelson 2003; Bertelson and Aschersleben 2003). Objectively measures could reveal that that the attractor stimulus has no effect on performance, albeit this conjecture is entirely speculative.

Besides the studies just mentioned, there is ample evidence that judgments of duration can be distorted in a variety of ways, in all modalities, and for all duration ranges. Subjective time can be sped up by sequences of clicks (Wearden, Philpott, and Win 1999; Penton-Voak et al. 1996), tones (Ono and Kitazawa 2010), and repetitive flickers (Droit-Volet and Wearden 2002), body temperature (Wearden and Penton-Voak 1995), stimulants (Wittmann, Leland, et al. 2007; Meck 1996), depressants (Allman and Meck 2012; Vachon, Sulkowski, and Rich 1974; Costello 1961), hallucinogens (Wittmann, Carter, et al. 2007), complex motor tasks (Brown 1985; Ivry 1996; Ferrandez et al. 2003), odd-ball stimuli (Tse et al. 2004; Liu et al. 2008), depression (Bech 1975; Blewett 1992), mania (Mezey and Knight 1965), attention deficit disorder (Smith et al. 2002; Barkley, Murphy, and Bush 2001; West et al. 2000), Parkinson's disease (Artieda et al. 1992; Perbal et al. 2005; Rammsayer and Classen 1997), and ageing (Wearden, Wearden, and Rabbitt 1997).

There are probably other examples of disturbances of duration perception or the subjective passage of time. It is commonplace to experience the passage of time in ways that does not conform to reality. For example, when we are engaged in something fun, time flies and when we are bored, it tends to drag on (Danckert and Allman 2005).

Besides the academic interest of explaining what is going on when our conscious experience of duration does not conform to our performance, one pressing concern is that subjective reports are used as data about clinical populations. If what I argued here is correct, and time perception and conscious experience of time can come apart, deficits in the perception of time could be misdiagnosed as deficits in conscious experience of time or the other way around. Being clear on this issue can help develop a better understanding of the etiology of those deficits in clinical populations and possibly lead to better treatments in a number of areas of concern to public health. In the final section of this chapter I will offer a model of perceptual duration distortions that can accommodate this distinction and can lead to testable predictions about their causes.

3 Looming Stimuli and Subjective Distortion of Time

To further explore the relationship between conscious experience of duration and perception of duration, I designed and implemented a pilot study in the Perception and Action Lab in City College of New York. These experiments focused on the subjective distortion of time caused by looming stimuli on a collision course with the face. Visual looming is defined as an increase in size over time, centered in a position directly in front of the perception. Auditory looming is defining as rising acoustic intensity. Presumably, looming and receding in other modalities would also involve modulation in intensity. This effect has been shown in multiple psychophysical paradigms with both visual and auditory looming stimuli and it is likely to exist in other modalities as well—I report on some of these studies below.

In one set of experiments, subjects were presented with two successive visual stimuli separated by an empty interval (Ono and Kitazawa 2010). The subjects' task was to estimate the duration of the empty interval. The visual stimuli flanking the empty interval were manipulated.

In the first experiment, subjects were presented with a small circle followed by a large circle in the looming condition and the reverse in the receding condition. The interstimulus interval was either 100, 200, 300, or 400 milliseconds. They were then asked to rate the interval using a scale of 1 to 4, where 1 is shortest and 4 is longest, and given no feedback on their performance. The results of this experiment showed that the duration of the empty intervals were judged to be significantly shorter in the looming condition than in the receding condition.

In the second experiment, the conditions remained the same, but the larger stimulus was a square, while the smaller was a circle. The results showed that the duration of the empty intervals were judged to be significantly longer in the looming condition than in the receding condition. What this suggests is that the disturbance in time perception observed in the first experiment was due to perceived motion in depth on collision with the face, as opposed to stimulus size.

In the third experiment, the conditions remained the same, and the two stimuli were circles, as in the first experiment. However, here the second stimuli was offset relative to the first, suggesting looming motion in depth that is not on collision course with the face. The results showed no significant difference between the subjects' judgments of the duration of the empty interval in either condition. This suggests that it is the collision path that is relevant to the disturbance in time perception observed in the first experiment.

In the fourth experiment, both conditions were looming, but here one was on collision course, and the other was offset. Subjects judged the duration of the empty intervals in the collision condition to be longer than in the offset condition. This suggests that the collision path is relevant to the disturbance in time perception, just as the third experiment.

In the fifth experiment, the subjects were presented with the same conditions as in the first experiment, that is, looming and receding circles, but were asked to judge which of the interstimulus intervals was longer relative to a third interval sandwiched between two crosses. This third interval was presented before either condition. The results showed that subjects judged the looming intervals to be significantly shorter than the receding ones, relative to the third interval. This comports with results from the first experiment.

The conclusion drawn from the abovementioned series of experiments also comports with data from other, similar paradigms with looming and receding stimuli (Wittmann, van Wassenhove, and Paulus 2010; Van Wassenhove et al. 2008). In these studies, subjects were shown 3 circles, each lasting for approximately 500 milliseconds followed by a target looming, receding, or steady-offset circle. The subjects were then asked to judge whether the target was longer or shorter than the preceding three. The results showed that the looming circles were judged to be shorter in duration than either the receding or steady.

These results are further corroborated by other work in a distinct line of research using 3-dimensionally rendered stimuli (Lin, Murray, and Boynton 2009; Lin, Franconeri, and Enns 2008; Franconeri and Simons 2003). In those studies, it was shown that peripheral looming stimuli capture more resources, as measured by reaction times, than looming stimuli close to the fovea (Lin, Franconeri, and Enns 2008). Also, looming stimuli not on collision course with the face cause a smaller distortion of time perception, as measured by reaction times (Lin, Murray, and Boynton 2009). The abovementioned experiments and the 3-dimensionally rendered paradigms are a stepping stone to the experiments outlined below.

4.1.1 Report of Experiment 1: Methods

The objective of the first experiment was to replicate the distortion caused by looming visual stimuli in a new paradigm. Unlike previous work with such stimuli, my experiments use a staircase paradigm typically used for detecting sensory thresholds. Following other work, the visual stimuli were 3-dimensionally rendered, in order to increase the threatening aspect of the stimuli.

In this experiment a fixation cross on a gray background was presented for 1000 ms, followed by either a 3-dimensionally rendered sphere or a steady 2-dimensionally rendered squiggle, 5 degrees of visual angle on either the left or right side of fixation. The 3D sphere stimulus was looming on a collision course with the subject's face and had a duration that is variable from trial to trial, between 40 and 2000ms. After 1000-1400ms, a second target appeared.

Fifteen participants participated in this experiment, but only data from 8 was used, due to a programming error, vision problems, and failure to complete the task properly. The participants were drawn from the diverse City College community and therefore reflect proportional representation of females and underrepresented minorities. All participants were between 18 and 35 years of age, with normal or corrected-to-normal vision, no history of neurological disease, and not currently taking medication with stimulant or depressant effects.

The stimuli were rendered by a program written by me in C++, taking advantage of the DirectX 10 3D graphics libraries made available by Microsoft Inc. All stimuli were presented on a cathode tube ray monitor to maximize the refresh rate of the screen (100 Hz) and enhance control and monitoring of stimuli durations. A fixation cross on a gray background was presented for 1000 ms, followed by either a 3D-rendered sphere or a meaningless, 2D squiggle, 5 degrees of visual angle on either the left or right side of fixation.

If the first stimulus was a looming sphere, the second one was a squiggle, and if the first stimulus was on the left, the second was on the right. After the two stimuli are presented, the participants were asked a forced choice question: "which was longer in duration?" Responses were made using the left arrow key (←) or right arrow key (→), corresponding to the side of the stimulus that they judge to have a longer duration. The participants were asked to respond only using a keyboard. I outline the procedure of a normal trial below, in Figure 3.

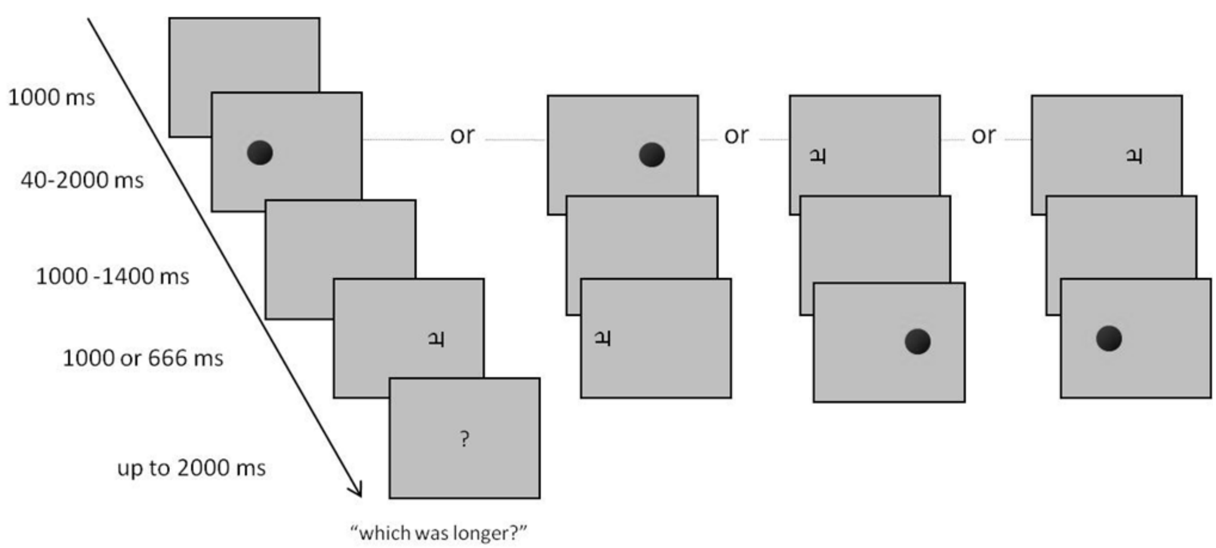


Figure 3. Experiment 1 task design.

The 3D sphere stimulus was looming on a collision course with the subject's face, which was positioned in a chinrest 80 centimeters from the monitor. The spheres had a duration that varied from trial to trial, between 40 and 2000ms. After the offset of the first stimulus, participants were presented with an empty interval between 1000 and 1400 milliseconds. Then the second stimulus appeared. If the first was a sphere, the second would be a 2D squiggle.[7] If the first was a squiggle, the second would be a sphere. The 2D squiggle lasted for 1000 milliseconds (long condition), 666 milliseconds (medium condition), or 444 milliseconds (short condition), depending on trial block.

The value of the looming stimulus in a series was $2300e^{-0.14x}$ where x is the index of the stimulus in an array of 30. For example, the 1st looming stimulus in the series was 2000 milliseconds, the 5th looming stimulus in the series was approximately 1110 milliseconds, and the 23rd approximately 100 milliseconds. Using this function made the staircase algorithm reach durations of interest, that is, durations close to steady durations, faster, thus shortening the amount of time participants had to take in order to complete a trial block.

Figure 4 below contains the curve with appropriately marked steady stimuli durations. The x axis corresponds to the index, and the y axis corresponds to duration. Durations beyond position 26 are not detectably different, and were never used, so they

[7] A 2D squiggle was used—as opposed to a stationary 3D sphere—on account of a pronounced location-independent motion after-effect observed during the experiment when the stationary stimuli were three-dimensional. Using the squiggle got rid of the motion after-effect, making it possible to better isolate the contribution of motion in depth to the perception of the sphere's duration.

are omitted from the graph. The vertical lines indicate durations of the steady stimuli. Note that steady duration are very close to where x is 6, 9, and 12.

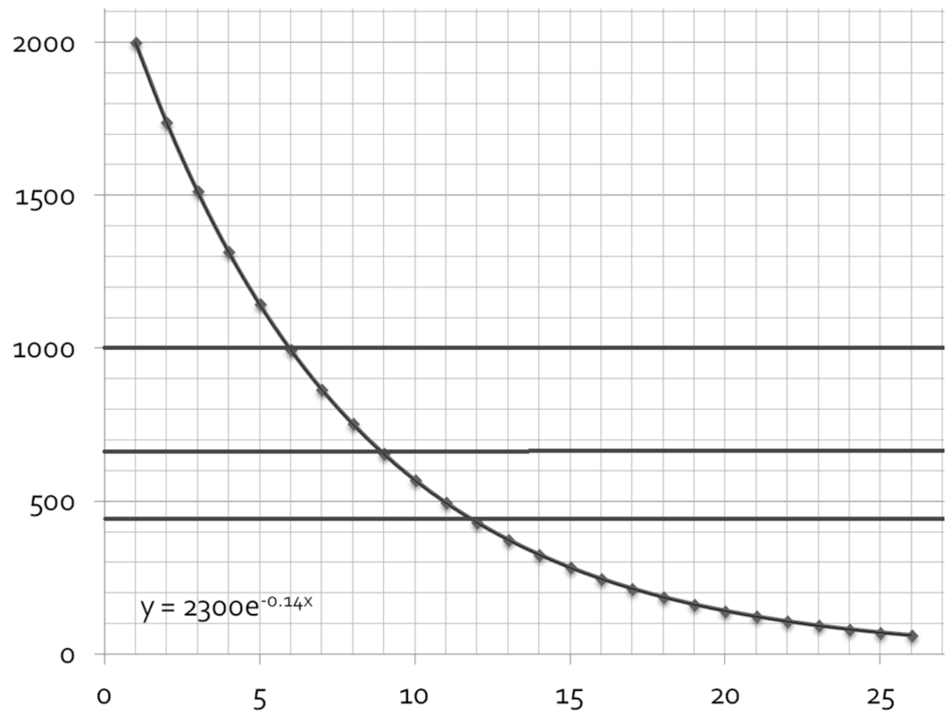


Figure 4. Curve shows target durations; vertical lines show steady durations.

At each trial, the duration of the 3D rendered sphere was on the screen changed in accordance with an amended version of the best PEST (best Parameter Estimation by Sequential Testing) algorithm used for sensory threshold detection (Pentland 1980). The best PEST is a staircase algorithm that determines which stimulus to present next based on response to previous queries. It was implemented using C++ as a part of the stimulus presentation program.[8]

[8] C++ implementation of this algorithm can be found attached in the Appendix in function: bool SystemClass::Threshold()

The amended version of the algorithm written specifically for the purposes of the experiment uses 3 variables CROSSOVER, CHECK, and INDEX and has the following procedure:

0) Set value of INDEX=0, CROSSOVER='false,' CHECK=0. Accordingly with the INDEX of 1, the first sphere stimulus presented has duration of 2000 milliseconds.
1) If the reply indicates that the sphere was perceived to be longer than the steady, the INDEX is increased by 1. The next sphere would then have duration specified in Figure 4 for that INDEX. This step continues until condition (2).
2) If the reply indicates that the steady was perceived to be longer, INDEX is increased by 1. The next sphere would then have duration specified in Figure 4 for that INDEX. However, in addition, CROSSOVER is set to 'true', indicating that a threshold was reached. At each subsequent time that the steady is perceived to be longer, CHECK variable is increased by 1 and INDEX are increased by 1. If the steady is perceived to be longer three times (until the value of CHECK=2), this verifies the threshold. At that point go to Step (4).
3) However, if the response indicates that the steady was perceived to be shorter before CHECK=2, this means that the threshold was wrong. Set CHECK=0, CROSSOVER=false, and INDEX=INDEX-CHECK. This brings the duration of the next sphere stimulus back to what it was the first time that the steady was first perceived to be longer. Go back to step (1)

4) CROSSOVER='false' and INDEX is decreased by 1. Repeat until the sphere stimulus is perceived to be longer than the steady. At that point set CROSSOVER='true', set CHECK=0, and decrease INDEX by 1. This indicates a second threshold, but coming from the opposite direction on the curve in Figure 4.
5) If the reply indicated that the sphere stimulus is perceived to be longer again, INDEX is decreased by 1, CHECK is increased by 1. This is repeated until either CHECK=2 or the steady stimulus is perceived to be longer. If the steady is perceived longer, set CHECK=0, CROSSOVER='false', and increase INDEX=INDEX+2. Go back to step (4). If CHECK=2, then the second threshold is verified and go to step (6).
6) If 4 thresholds are verified (2 coming from top and 2 from bottom of the curve), average them and EXIT. This average was then used as a data point for steady duration. If only 2, go back to step (1).

Completing (1)-(6) and reaching EXIT yields 4 thresholds for each steady duration: two coming from the top of the curve in Figure 4 down and two thresholds from the bottom up. To successfully complete the experiment, each participant had to complete (1)-(6) for each of the 3 duration of the steady stimulus. This yields a total of 12 thresholds.

4.1.2 Report of Experiment 1: Results

Analysis of the results shows a significant effect of visual looming on collision-course with the face on the conscious experience of duration. Measured across 8 participants, a steady visual stimulus that is 1000 milliseconds is judged to have the same subjective duration as a looming stimulus that is 764.065 milliseconds; a 666.666 steady is judged to have the same duration as a 455.635 looming; and a 444.444 is judged to have the same duration as a 253.481 looming. These results are outlined in Figure 5 below.

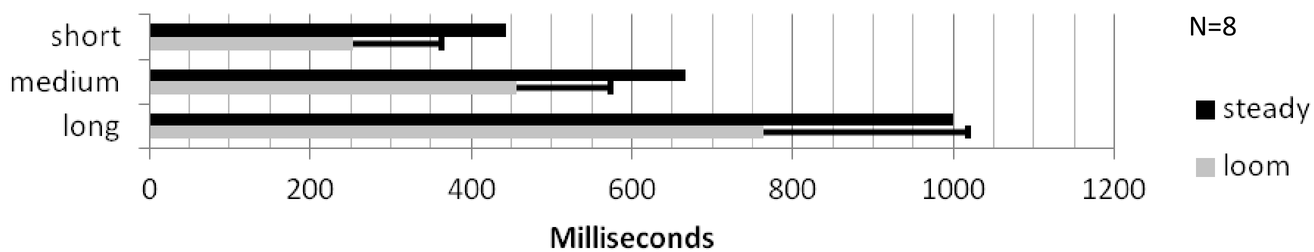


Figure 5. Behavioral results of Experiment 1.

On average, the duration of looming visual stimuli tends to be underestimated relative to a steady visual stimulus, suggesting a dilation of subjective time. This shows that when an object is on collision-course with the face, participants' judge it to be shorter than it is, corroborating results from other studies.

4.2.1   Report of Experiment 2: Methods

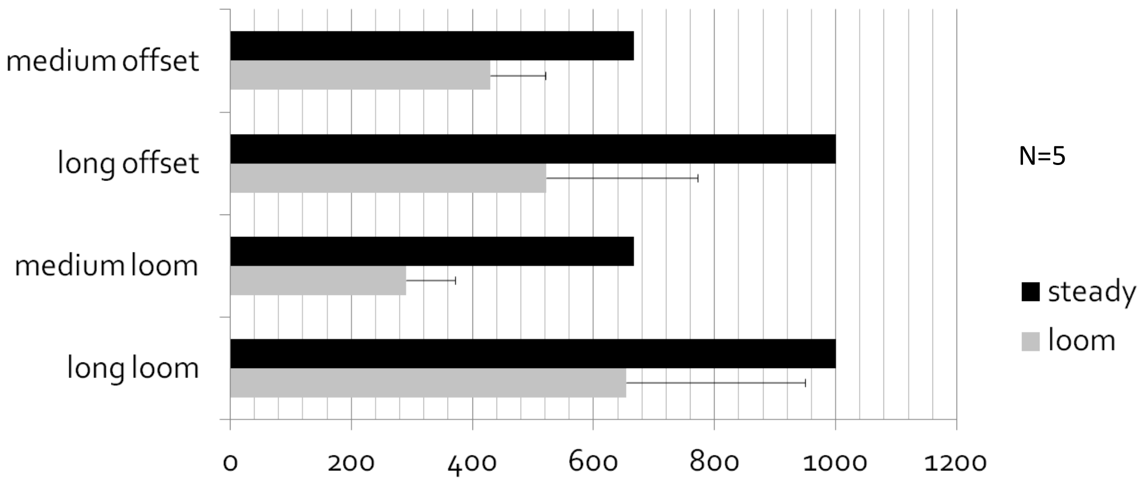
The aim of this experiment was to see whether the results with offset looming stimuli reported in other studies (Ono and Kitazawa 2010; Lin, Franconeri, and Enns 2008; Lin, Murray, and Boynton 2009) could be replicated using the staircase paradigm. In those studies, it was reported that offset visual looming stimuli do not cause the time dilation effect observed in looming stimuli on collision course with the face.

The procedure in the second experiment followed that outlined in the methods section of experiment 1. The important difference was that this time participants were also presented with looming 3 dimensionally rendered spheres that were slightly offset from collision course with the face. The steady stimuli were either 1000 or 666 milliseconds and were presented in distinct blocks. The 444 millisecond duration used in the previous experiment was not used. Then the results in the offset blocks were compared with looming blocks for each participant. A total of 5 participants, 3 male and 2 female, completed this experiment.

4.2.2 Report of Experiment 2: Results

Offset and looming blocks where the steady stimulus was 666 milliseconds were significantly different. The offset looming stimuli were on average perceived to be 139 milliseconds longer than looming stimuli, relative to a 666 millisecond steady. This result comports with previous findings, which showed that offsetting the looming stimulus decreases or gets rid of the time distortion effect.

Offset and looming blocks where the steady stimulus was 1000 milliseconds showed no significant difference. The offset stimuli were judged to be shorter than the looming stimuli, by about 120 milliseconds, on average. This does not comport with previous studies of looming and offset visual stimuli, which showed offset having a much bigger effect and in the opposite direction (Ono and Kitazawa 2010; Lin, Franconeri, and Enns 2008; Lin, Murray, and Boynton 2009). The results are summarized in Figure 6 below.



	long loom	medium loom	long offset	medium offset
steady	1000	666.666	1000	666.666
loom	654.338	290.0322	522.1122	429.1322

Figure 6. Behavioral results of Experiment 2.

The time dilation effect found in the 666 millisecond condition did not also exist to the same extent in the 1000 millisecond condition. One possible explanation of this is that there are multiple timing mechanisms operating at different duration ranges. Longer looming stimuli could engage one of these more than the other mechanisms (more in the discussion section).

4.3 Report of Experiments 1 and 2: Discussion

As predicted, experiment 1 replicated the subjective time dilation effect caused by looming stimuli, which was observed in other paradigms. One advantage here is the use of a new paradigm, which can be used to shed light on the mechanisms underlying this distortion. Additionally, the experiment was observed to induce a pronounced motion after-effect, which was not location specific, and hence unlike other motion after-effects, such as the waterfall illusion. The latter finding promises a new avenue of fruitful research into time and motion perception.

In experiment 2, however, the results were surprising and not a complete replication of previous findings that use different paradigms. The offset looming stimuli were on average perceived to be 139 milliseconds longer than looming stimuli, relative to a 666 millisecond steady, comporting with previous findings (Lin, Franconeri, and Enns 2008; Lin, Murray, and Boynton 2009; Ono and Kitazawa 2010). However, offset and looming blocks where the steady stimulus was 1000 milliseconds showed no significant difference.

This is surprising, but only if we assume a single mechanism for handling duration perception. Regardless of which model turns out to be right, there are good reasons to think that duration processing in the subsecond range is carried out by a distinct mechanism. Important evidence supporting the view that subsecond durations are processed by a distinct mechanism comes from pharmacological studies. There is also evidence from fMRI recordings and trans-magnetic stimulation for the same conclusion.

One pharmacological study tested the effects of haloperidol, which blocks dopamine reception, midazolam, which is a sedative, and scopolamine, which is used to fight motion sickness, on duration judgments (Rammsayer 1999). Participants were asked to perform two temporal discrimination tasks after administration of one of the three compounds or a placebo. Participants were first presented with two stimuli of various durations between 50 and 1000 milliseconds and then asked to determine which of two stimuli was longer.

Haloperidol was shown to cause strong decrease in the accuracy of judgments for durations in the range of milliseconds. Midazolam and scopolamine did not differ much from placebo, which has minimal affect on such judgments. However, both haloperidol and midazolam caused a strong decrease in the accuracy of judgments comparing durations over one second. Scopolamine, however, was found to have no significant effect on duration judgments over one second. These results strongly suggest that processing of durations in the subsecond range is handled by a mechanism that is distinct from the mechanisms that processes longer durations.

Converging evidence strongly suggests that one of neural structures critical to processing temporal information in the subsecond range is the cerebellum (Salman 2002, for review). The cerebellum is known to be critical to the coordination of motor tasks, which require perceptual feedback. It makes sense for the cerebellum to be involved in temporal sensation in the subsecond range since that would be the range most important to movement and the cerebellum is known to be the seat of motor processing (Kornhuber 1971). Complex motor tasks rely not only on spatial information, but also on information about how events, including one's own movements, unfold in time.

The cerebellum is made up exclusively of fast transducers that compose feed-forward networks and display a high degree of modularity (Marr 1969). Such transducers operate by mere propagation of signal from one node to the next without any loops or feedback to earlier stages of processing. The anatomy of the cerebellum makes it conducive to fast, cognitively impenetrable processing, which has been demonstrated to be the hallmark of processing duration in the subsecond range (Rammsayer and Lima 1991; Lewis and Miall 2003). Interestingly, some of these cerebellar transducer networks have even been shown to behave like an oscillator clock (Ito 2002). Focal lesions in the cerebellum impair performance on a range of perceptual and motor tasks, all of which involve fine temporal discrimination (Ivry, Keele, and Diener 1988; Spencer et al. 2003; Ivry et al. 2002).

Furthermore, shutting down the cerebellum with electromagnetic pulse (TMS) impairs performance on a range of perceptual and motor tasks in a similar way (Koch et al. 2007). In that study, participants were asked to reproduce the duration of a visually presented stimulus by pressing a button after repeated TMS of the cerebellum or right dorsolateral prefrontal cortex (rDLPFC). After the repeated TMS of one of these regions, a succession of stimuli was presented. First, participants were presented with a blue circle, and then a red circle, which appears in its place.

The durations of the stimuli varied. 50 trials consisted of stimuli between 400 and 600 milliseconds and 50 trials of stimuli between 1600 and 2400 milliseconds. The task facing the participants was to press a button after the presentation of the red circle when an interval of time passes that they judge to be equal to the interval of time passed during the presentation of the blue circle.

It turns out that repeated TMS of the left cerebellum induces overestimation of the subsecond intervals, but does not interfere with suprasecond intervals. And repeated TMS of the right cerebellum altered nothing. Finally, repeated TMS of the rDLPFC induced overestimation of suprasecond intervals, but does not interfere with subsecond intervals.

This is evidence that the cerebellum is involved in processing subsecond durations and the rDLPFC the suprasecond intervals. In a second series of experiments in this study TMS was applied selectively at different times to these structures, to determine whether the effect was the result of retrieval or encoding during perception. TMS to these areas early on would, presumably, affect encoding, while TMS later on would affect retrieval.

Repeated TMS of both the right and left cerebellum during the encoding phase, meaning relatively closer to the onset of the stimulus, resulted in overestimation at the millisecond range. And repetitive TMS slightly later did not produce an effect at all. This suggests that the cerebellum is important to processing time and is not involved in retrieval or reproduction. This is strong evidence that the cerebellum is the likely location of the subsecond temporal mechanism.

The lesion and TMS studies support the view that the cerebellum processes perceptual information about time. In a similar vein, neuroimaging studies report activity in the cerebellum during performance of tasks requiring subsecond temporal processing (Lewis and Miall 2003, for review).

This conclusion is further strengthened by an independent set of results that implicates the cerebellum in Pavlovian conditioning. Puffs of air to the eye cause the eyelid to close and when the puffs are accompanied by tones, after a period of training the eyelid closes with only the tone (Kim and Thompson 1997). It has been shown that the timing of the stimuli is both necessary and sufficient to this kind of conditioning (Kalmbach, Ohyama, and Mauk 2010). The temporal specificity of this conditioning is explained by the firing rate of neurons in the cerebellum (Medina et al. 2000). This shows the critical role that the cerebellum plays in processing timing in the subsecond range, when it comes to motor conditioning.

Finally, there is evidence that the cerebellum is involved in improving performance on timing tasks. Participants trained in motor tasks that have a distinct temporal component, such as a tapping rhythm, perform better on the task after sleeping (Lewis, Couch, and Walker 2011). And fMRI recordings comparing these participants' brain before and after sleep show distinct changes in, among other structures, the cerebellum (Lewis, Couch, and Walker 2011, p. 119). In conclusion, empirical data strongly suggests the cerebellum is most important to processing timing information in the subsecond range. Other structures such as the basal ganglia, striatum, and thalamus are also involved in processing temporal information in the subsecond range, but not as much as the cerebellum (Lewis and Miall 2003).

Very different neural structures are involved in processing durations longer than a second. Unlike processing of shorter durations, most of these structures have multiple purposes and are involved in more sophisticated cognitive processing (Pöppel 1997). One of these structures is the dorso-lateral pre-frontal cortex, which is known to be involved in decision making and cognition (Koch et al. 2007).

The existence of multiple duration mechanisms bears on the results of experiment 2. In that experiment, no significant difference was found in the long offset and long looming conditions. This contradicts previous findings that show offset looming visual stimuli having an opposite or no effect compared to looming visual stimuli on collision course with the face.

The data summarized in Figure 6 most likely reflects the operation of different duration mechanisms. The sub-second mechanism was involved in processing medium offset and medium looming stimuli. The supra-second mechanism was involved in processing long offset and long looming stimuli.

This suggests that the content of duration judgments in the subsecond range is determined by mechanisms distinct from those that determine the content of other judgments of longer durations. Of course, it does not seem that way to us. And this bears on another issue, which is the distinction between the mechanisms of time perception and the mechanisms of conscious experience of time.

If all we had to go on was the way that things seemed to us in conscious experience, we would probably never even ask the question of whether we use more than one mechanism in estimating duration. The judgments that we make about the duration of a subsecond stimulus seem to have the same basis as the judgments we make about longer stimuli. We have no awareness of the nature of the underlying mechanisms at all.

This is corroborated by post-experiment briefings of participants in experiment 2. 3 out of 5 of the participants that completed the task reported having no awareness of the difference between trial blocks where the looming sphere were on collision course with the face and those where they were offset. This suggests that if the effect of offset looming is indeed smaller than the effect of looming on collision course, then it is independent of awareness. This is something that future work with this paradigm will explore further.

The distortion of subjective time observed in experiments 1 and 2 is likely the result of altered processing at the level of perception. A dedicated system for processing threatening stimuli, such as those on collision course with the face, is most likely the cause of the effect. We have several reasons to think that such a mechanism is independent of the mechanisms responsible for conscious experience.

It has been observed that Rhesus monkeys are afraid of both looming visual and looming auditory stimuli (Ghazanfar, Neuhoff, and Logothetis 2002; Maier et al. 2004; Schiff, Caviness, and Gibson 1962). Defensive behavior to looming visual stimuli persists in the Rhesus even with substantial lesions in the visual cortex, suggesting alternative and dedicated pathways that involve the superior colliculus (King and Cowey 1992).

Other research strongly suggests that monkeys have a poly-sensory region in the ventral intraparietal area responsive to threatening stimuli close to the face (Graziano, Wheeler, and Gross 2000). Monkeys typically move their arms to cover the face when responding to such stimuli. And electric microstimulation of this area produces similar defensive hand movements covering the face (Cooke and Graziano 2004).

In humans, some researchers point to the superior colliculus, pulvinar nucleus of the thalamus and the anterior insula as regions responsible for processing looming threatening stimuli (Billington et al. 2011). For sounds, it has been observed that auditory looming stimuli are also treated as a warning cue and engage the amygdala (Bach et al. 2008; Bach et al. 2009). The involvement of the amygdala and the superior colliculus suggests an alternative pathway for looming stimuli, similar to that posited in the Rhesus.

A polysensory system, similar to that observed in monkeys and which is specifically dedicated to processing threatening stimuli close to the face, might exist in humans, and might underlie processing of looming stimuli for both audition and vision. In fact, there is already evidence that looming audio-visual stimuli are selectively integrated and facilitate behavior measured by reaction times (Cappe et al. 2009). Furthermore, analysis of evoked response potentials in trials involving audio-visual looming stimuli suggests enhanced early neural processing for such stimuli relative to receding or mixed looming-receding audio-visual stimuli (Cappe et al. 2012).

Just as in the Rhesus, the most likely location for such a polysensory system would also be in an interperiatal area. The areas also involves would be the superior colliculus and the frontal eye fields, which are generally thought to involve unconscious processing. And if that turns out to be the case, then we would have little reason to think that the effect involves the mechanisms of consciousness.

The staircase paradigm developed for experiments 1 and 2 can help shed light on the brain regions involved in time perception. The displays in those experiments randomly showed target stimuli on one of two sides of the screen, thus making it possible for participants to report with eye movements. Previously, it has been shown that reports with eye movements engage information processed by a distinct perceptual mechanism relevant to temporal order judgments (Ro et al. 2001).

In that study, there were two groups of participants. The first were people with unilateral lesions to the inferior parietal lobe (IPL). The second were people with lesions in the dorsolateral prefrontal cortex (dLPFC) including the frontal eye fields (FEF).

These groups were first presented with a fixation in the center of a computer screen for 2 seconds. Afterwards, they were presented with a filled gray square stimulus on a light gray background, in one of their visual hemifields, 10 degrees of their visual field to the left or right of fixation. Then an interstimulus blank screen was presented for either 0, 50, 100, 150, 200, or 250 milliseconds. Finally, participants were presented with another filled gray square, 10 degrees to the left of right of fixation. The location of the second gray square depended on the location of the first. For example, if the first gray square was on the right, then the second would be on the left.

After the second presentation, participants were asked to make a temporal order judgment about which of the squares came first in time. In the manual task, participants were asked to indicate which of the two gray squares came first by pressing one of two buttons. In the ocular task, participants were asked to direct their gaze to the hemified in which a square appeared first.

The results showed that participants with parietal lesions have an ipsilesional bias in saccades in the ocular task. However, they do not exhibit such a bias when asked to give their responses using one of two buttons. Participants with frontal lesions showed no ipsilesional bias in either task.

This suggests that neural pathways involved in direct visuomotor responses may be dissociated from those involved in conscious visual perception. The IPL is likely involved in saccade generation independent of conscious perception, which contradicts the dominant view that frontal areas, such as the dLPFC are alone responsible for motoric bias. Such bias can result from the operation of an independent circuit, which bypasses consciousness and involves the parietal areas.

These findings lay the foundation for future work that builds from experiments 1 and 2. Future experiments will test whether saccadic eye movements and motor responses can be dissociated in the way that was found in patients with parietal lesions. My working hypothesis is that participants' eye movements will not be affected by time distortion caused by looming visual stimuli in the same way as the mechanisms responsible for their subjective reports as collected by button responses. In other words, the participants' button presses are expected to conform to results of experiments 1 and 2, but their ocular responses will not.

If this hypothesis is confirmed, one interpretation of the results could involve the distinction between the so-called ventral visual stream, which is thought to be involved with conscious visual experience, and the dorsal stream, which is involved with "vision for action" (Milner and Goodale 2008; Goodale and Milner 1992). On the other hand, if there is no statistically significant difference between reports using eye movements and button presses, this would suggest that subjective time distortion caused by looming visual stimuli happens at the level of low-level perceptual mechanisms.

5 Temporal Mental Qualities and Subjective Time Distortions

The experiments reported on in this chapter shed light on a class of time distortions caused by looming visual stimuli. First, they suggest that the time distortion caused by looming stimuli occurs at the level of perception, independently of awareness. Secondly, the second experiment in particular, that offset looming stimuli do not affect the distortion of duration in the same way for all duration ranges.

The temporal quality model fits well with the abovementioned results and in particular with the conclusion that the mechanisms of time perception are independent of the mechanisms of conscious experience of time. Temporal qualities are a part of the explanation of the hierarchy of perception and not of mechanisms of conscious experience. According to the temporal qualities model of time perception, temporal mental qualities play a crucial role in discriminations of timing and duration in the environment.

Given that role, it is no surprise that temporal mental qualities are instantiated in perceptions independently of awareness. This is because it is perception that drives performance of those discriminations, not awareness of perceiving. Perception is important to discriminations, while conscious experience is connected to subjective verbal reports, which are not important to such discriminations.

According to the temporal quality model of time perception, perception of duration is occurs when one's perception instantiates appropriately related timing qualities. These timing qualities are instantiated whenever we discriminate change in a perceptible property, such as a color or sound. Change discriminations are made possible by timing qualities in the same way that color and sound discriminations are made possible by color and sound qualities.

However, change discriminations are different from discriminations of colors or sounds in that they depend on detection of onset and offset of those perceptible properties. When we detect onset of a sound we discriminate an auditory change. Similarly, when we detect a change in color we discriminate a color boundary or a change in color.

Given this, we can think of change discriminations as depending on discriminations of other perceptible properties. For example, when the mental quality of a flute B* is followed by a C* we typically make an auditory discrimination of change—and this is even when no such change occurred in the environment. However, when no new quality is instantiated after the B* no change is detected, either. It is hard to imagine what it would mean for one to discriminate an auditory change without a corresponding difference in auditory qualities.

This is why change discriminations underlie our perception of time. As William James pointed out, “awareness of *change* is thus the condition on which our perception of time's flow depends” (James 1890, ; James' italics). Invariably, in the world we inhabit, the offset of a property comes after its onset. There can be no offset of a flute A without prior onset of that A. And the onset of the A comes after the offset of silence, or some other auditory quality or qualities.

One might doubt that change requires sensory perception distinct from the perception of sounds and colors, and so on, as the temporal quality model predicts. But there is a good reason to think that indeed change is a distinct feature of perception and that it can occur without awareness. We can sometimes fail to make a discrimination of change, while still perceiving sounds and colors, and so on. There is also evidence that we can do so without being aware of it.

In vision, when we are distracted by a mud splash on the screen, a blink, or a saccade this leads to temporary change-blindness (Simons and Levin 1998; Rensink, O'Regan, and Clark 1997; Simons and Levin 1997). Sometimes, the changes that are obscured by the distractor can be quite large and perceivers report seeing no change at all. Nonetheless, when people are forced to guess about features of the change they perform significantly above chance, suggesting that they perceive change even without being aware of it (Fernandez-Duque and Thornton 2000).

In that set of experiments, participants were presented with 8 rectangles arranged in a circle and oriented either vertically or horizontally. After 250 milliseconds the rectangles disappeared. After 250 milliseconds of the blank screen, the 8 rectangles were presented again, for 250 milliseconds, but this time one of them was rotated by 90 degrees. After these rectangles offset, another set of 8 rectangles was presented for 20 milliseconds, but this time one of the rectangles was white. Sometimes, the white rectangle was in the same location as the one that changed its orientation, but at other times, it was in a location of circular display opposite to the changed rectangle. For example, if the changed square was at 5:00, the white square would be at 11:00.

After the last display, participants were asked to discriminate the orientation of the white square and then to say whether they have seen the change in the 8 rectangles. Participants pressed one of two keys on a computer keyboard to indicate the orientation of the white rectangle. And then they pressed the space bar to indicate that they have seen a change and did nothing if they did not see a change.

Participants responded more slowly and inaccurately when the white rectangle was not oriented in the same way as the changed rectangle. For example, if one of the rectangles changed from vertical to horizontal and then the white rectangle was vertical, participants were worse in detecting the change. If the changed rectangle and the white rectangle were oriented in the same way, they were better at detecting change.

Importantly, this effect occurred regardless of whether the rectangle that changed was in the same location as the white rectangle. If participants were better at detecting change only on trials where the location of the changed rectangle and the location of the white triangle were the same, then the effect would be the result of spatial localization. Two similar stimuli in the same part of the visual field facilitate detection.

However, given that the effect depended on the orientation of the changed and white rectangles being the same, this shows that change detection can be facilitated regardless of location. That suggests that change is a distinct aspect of perception. It also shows that change detection can occur without awareness, since participants were not aware of the relationship between orientation of the white rectangle and their performance.[9]

All of this suggests that change is a distinct aspect of perception, of which we can sometime be unaware. We sometimes fail to discriminate change or misperceive it, just as we might fail to discriminate perceptible properties, such as colors and sounds. This is exactly what the temporal quality model predicts.

The model also provides a ready explanation of what happens when timing and duration are distorted, as is the case with looming stimuli on collision course with the face. When we perceive something as longer than it is, the temporal qualities

[9] This paradigm has been criticized for placing the white rectangle always on the opposite side of the location of the changed rectangle. In a set of experiments, (Mitroff, Simons, and Franconeri 2002) showed that the congruency effect disappears without the spatial relationship between the white and changed rectangles, thus suggesting that participants can easily learn the relationship and use it in a conscious strategy that facilitates change detection. However, (Fernandez-Duque and Thornton 2003) corrected for the confound and replicated the effect. Furthermore, Mitroff et al's methodology has been criticized (Laloyaux, Destrebecqz, and Cleeremans 2006) and the original results have been replicated by an independent party (Laloyaux et al. 2008).

instantiated in that perception do not accurately reflect the onset and offset of the relevant properties in the environment. The result is a duration quality that does not correspond to the duration of the stimulus.

For example, if we perceive a 666 millisecond looming sphere as 350 milliseconds, presumably we detect the onset of that visual stimulus correctly. However, for whatever reason—whether it is increased attention or the arousal caused by the threatening nature of looming—the temporal quality marking the offset of the sphere is instantiated sooner than it would for a steady or receding sphere. Consequently, the duration of the sphere is perceived to be shorter than it actually is, which is reflected in the discriminations that we make about its duration. Similar explanations can be generated for other distortions of duration, which I mentioned earlier in this chapter.

In all distortions of duration, it could turn out that perception is misrepresenting duration in the way in which I just suggested. But that is not the only possible explanation of what happens when the data collected involves the subjects' subjective reports. It could also be the case that the subjects' their conscious experience presents them with the distortion, while their perception gets it right, as some researchers already suggested (Lamotte, Izaute, and Droit-Volet 2012).

Hence, the temporal quality model is not a complete account of time distortions. In order to have a complete account, we also need a model of the distortions that occur only at the level of conscious experience. I have already hinted at what such a model would look like throughout the dissertation. The task of the next chapter is to make it explicit.

In this chapter I presented evidence for one of the predictions of the temporal quality space model of time perception, namely, that we can perceive time without being aware of it. This prediction is a consequence of that model's reliance on discriminations as the method of individuating individual mental qualities. This criterion relies on the functional role that mental qualities play in an organism's overall mental economy.

I also reported on experiments that show a significant time distortion caused by looming stimuli. The paradigm used in those experiments in novel and can lead to future work that will shed light on the involvement of alternative and unconscious circuits in time perception. A discovery of such circuits would further strengthen support for one of the key predictions of the temporal quality space model, namely, that time perception can occur without awareness.

CHAPTER 5: Conscious Time Perception

1 Conscious Perceptions of Time

The previous chapters' discussion of the neural processes involved in temporal processing gives overwhelming support to the view that time is perceptually processed unconsciously and can be represented by sensations that are themselves unconscious. This is predicted by the temporal mental quality space model. On that view, temporal mental qualities can be instantiated in perceptions of which we are completely unaware.

In the following I lay out a theory of conscious experience that takes into account the theory of sensation given in the previous chapters. This theory of conscious experience serves as the framework within which I give an account of the conscious experience of time. And, with that in place, I finally give an account of the experience of succession.

2.1 The Ways We Are Conscious

When we are completely unaware of having a mental state that mental state is unconscious. Conversely, when a mental state occurs consciously, we are always aware of having it. Furthermore, when we are aware of a mental state, we are aware of it in some way. We are aware of a sensation as being a sensation of red, for example, or as a thought about a cat. We are never aware of having a mental state full stop. All of these platitudes are an important part of our folk-psychological conception of consciousness

In normal circumstances one is aware of a sensation in a way that characterizes the mental qualities that the sensation instantiates. For example, one is typically aware of a sensation of snow as being white or cold. And, finally, when one is aware of a sensation in that way, one is presented with a white and cold conscious experience.

But sometimes one is aware of our sensations in less typical ways. For example, one can be aware of a tickle in a way that makes it appear to be a pain. And one can be aware of a sensation of snow in a way that makes it appear hot. Conscious experience can presents us with a certain amount of illusions. So if we can be aware of having a sensation in one way, then we can also be aware if that very sensation in another way.

Nonetheless, while conscious experience sometimes presents us with distortions, they almost invariably seem to be veridical. Illusory pain is, it seems, still pain. This sense of veridicality is the result of the way in which we are aware of sensations. Conscious experience presents the world to us directly and in a way that seems unmediated. We seem to look through our awareness of sensations, and the sensations themselves, directly to the things we sense.

The abovementioned folk psychological platitudes about conscious experience are taken into account by, among others, the higher-order thought theory of consciousness (Rosenthal 2005, 1986). On this view, we are aware of mental states such as sensations in virtue of having a thought that represents us as having those very states. These higher-order thoughts are themselves typically unconscious and independent of any conscious inference.

Since higher-order thoughts typically occur unconsciously and independently of any conscious inference, the mental states they are about appear to us in a direct and unmediated way. Consequently, the mediating factors in conscious experience—whether it is an inference or the mere presence of the higher-order thought itself—are typically not a part of the way we are conscious of our mental states.

Higher-order thought theory also explains what determines the various ways in which we can be conscious of our sensations. Higher-order thoughts can describe sensations in many ways. For example, a higher-order thought in virtue of which we are conscious of having a sensation of crimson, describes it in terms of the location of crimson* in the color quality space.[10] And the description results in us having a crimson conscious experience.

But the higher-order thought could have equally described the sensation of crimson in terms of the location of red* in the color quality space. Either description determines what it is like to have such a conscious experience, without affecting what mental qualities the sensation actually has. In that way higher-order thoughts fully determine how our sensations will appear to us as being.

On this view, higher-order thoughts also describe qualitative states in terms of their location in the temporal quality space. For example, a conscious sensation of a red dot followed by a conscious sensation of a blue dot will locate the color qualities along the one-dimensional temporal quality space. Consequently, the timing* of red* will appear to one to be before the timing* of blue*. And if the higher-order thought can represent timing by describing timing* qualities in that way, it can thereby represent duration as well.

[10] The asterisks mark a mental quality, as opposed to a perceptible property. For example, red* is a mental quality that corresponds to perceptible red in the world.

As argued in chapter 3, timing* qualities are the mental boundaries of durations*, so a higher-order thought that characterizes a sensation in terms of timing*, can also describe it in terms of duration*. This is a straightforward consequence of the way in which the temporal quality space is defined—as a space of similarities and differences between timing* qualities, that can flank duration* qualities.

2.2 Verbal Expressions of Temporal Judgments

Verbal expressions of perceptual judgments can be used as criteria for consciousness (Seth et al. 2008; Dienes and Perner 2004). This is because verbally expressed thoughts are typically conscious. But, of course, we sometimes express mental states without being in any way conscious of them. We can grimace when we see someone act vulgarly without realizing we have done so. Or groan in our sleep in response to a noise.

When the expressed mental states are not conscious, they are also not reportable. Being completely unaware of a mental state precludes it from being sincerely reported on. Consequently, we can assume that awareness of one's mental states is crucial to being in a position to sincerely report on them. While we can express unconscious mental states, we cannot report on them.

Verbal expressions of temporal judgments are presumed to be connected to sensations. And the intentional content of verbally expressed temporal judgments corresponds in some way to the sensations that are causally related to them. Without both the causal and semantic connection, eliciting temporal reports from participants wouldn't have the role it does in perceptual psychology. Both connections are a part of our most basic folk psychological conception of mentality.

On this view, sincere expressions always have intentional content that reflects the intentional content of the underlying mental states. For example the expression "that is a lie" ostensibly expresses a belief that something is a lie. But that is not really so with sensations; no verbal expression seems to be able to express the qualitative character of sweetness, or the temporal qualitative character, if there is any. Verbal expression can only express intentional content such as "this candy is sweet" rather than the qualitative character of sweetness.

It might seem that perceptual judgments are expressions of non-perceptual thoughts. But, at least on Rosenthal's view of mental qualities, mental qualities are not intentional, so their qualitative character cannot be verbally expressed. However, we do express perceptual judgments that are based on our sensory states, so what role do these states play in the expressions?

On Rosenthal's view, verbally expressed judgments have intentional content that corresponds to the intentional content associated with a particular sensation. And that intentional content together with the qualitative character are a single perception. So perceptions have both qualitative character and intentional content. Finally, verbally expressed perceptual judgments are expressions of that perceptually tied intentional content.

If verbal expressions of perceptual judgments were expressions of non-perceptual thoughts, then we could form Moore's Paradox sentences with them. Sentences such as "that is sweet and I do not taste that is sweet" would seem paradoxical in the same way in which the sentence “that is a lie and I do not think it is a lie” seems paradoxical. But they don’t; there is no perceptual Moore’s Paradox.

Moore’s Paradox sentences are formed by conjunctions of an expression of a thought and a contradicting report about that very thought. The sentence “that is a lie” expresses a thought, while the sentence “I do not think that is a lie” is a report about that very thought. We cannot simultaneously affirm and deny these two sentences without creating confusion; “that is a lie but I do not think that is a lie” seems nonsensical because it is ostensibly about the same thing being true and false.

But the air of paradox surrounding such sentences is the result of a tension between performance conditions, not the truth conditions of the two sentences (Rosenthal 2005, p. 50-3). When we say “that is a lie”, we might as well be saying “I think that is a lie,” even though the truth conditions of these two sentences are clearly are not the same. So, when we add a “not” into “that is a lie, but I think that is a lie,” we seem to create a contradiction in the truth-conditions, but in fact we create a tension in the performance conditions.

When we sharpen the distinction between expressing and reporting, the sentence “that is a lie but I do not think that is a lie” is clearly a conjunction of an expression of a thought about a lie and a report about that very thought. But then we also see that the two conjuncts express two different mental states. As such, they do not form a logical contradiction, but simply an odd speech act.

We can’t create the same air of paradox for perceptual judgments. The sentence “that is sweet but I do not taste it is sweet” is perfectly natural. In fact, we often use sentences like it to express the distinction between the way we believe the world to be and the way it presents itself to our senses.

“That is sweet” can be used to express the intentional content of a non-perceptual thought. And the sentence “I taste that is sweet” is a report about a perception, which cannot also be used to express a non-perceptual thought. Consequently, when the negation of the report is conjoined with the expression, there is no appearance of contradiction.

But "that is sweet" can also be used to express a perceptual thought. In the sentence “that is sweet but I do not taste that is sweet," however, the perceptual reading is suppressed by our semantic machinery. When we keep that in mind the impression that "that is sweet" expresses a non-perceptual thought as opposed to the intentional content of a perception is dispelled.

The temporal judgment that “a red stimulus occurred before a blue stimulus” expresses the intentional content of a perception of something as red and as occurring before something blue. And a judgment that “a red stimulus was longer than the blue” expresses the intentional content of a perception of the stimulus as red and as having a duration that is longer than the blue stimulus.

The verbal expression “the red flash occurred before the blue flash” is performance-equivalent to “I saw that the red flash occurred before the blue flash.” We could use either sentence to express the judgment that the red flash happened before the blue flash. But the expression and the report have distinct truth conditions—the first is ostensibly about the flashes and their timing, while the latter is about a perception.

Ultimately, all of the above shows two things relevant to the present discussion. First, verbal expressions of temporal judgments inherit their intentional content from temporal perceptions. Temporal perceptions, therefore, have intentional content. Second, perceptions are not just thoughts. If perceptions were thoughts, we could form Moore's Paradox sentences involving verbs such as "taste" and "see"; alas we can't. Together, these two points support the temporal quality space model. This is because the way that we express the content of conscious states depends on the way that we are aware of those states. And the way that we are aware of it is independent, on my view, from the role that that state plays in our mental economy.

Sincere expressions always have intentional content that reflects the intentional content of the underlying mental states. The expression "that is a lie" ostensibly expresses a belief that something is a lie, for example. The same holds for reports—invariably, they reflect the intentional content of the mental states they express.

Expressions of mental states also reflect the illocutionary force of the underlying mental states. Verbal expressions of thoughts will have a different illocutionary force from verbal expressions of desires, even though the two might have the same content (Vendler 1972). Desires are satisfied or frustrated by states of affairs in the world, while thoughts are made true or false by states of affairs the world (Searle and Vanderveken 1985, p. 52-3). Verbal expressions of thoughts will always be assertoric, reflecting the assertoric force of the underlying thought. This shows us something important about the nature of the mental states that we verbally express, namely, their illocutionary force, which can be used to individuate them alongside their content.

Reports of mental states always have assertoric illocutionary force. This is because reports assert that something is the case. For example, the report "I think that is a lie" is about a thought, and if the thought doesn't exist, or it isn't about a lie, then the report would be false.

Given the assertoric force of verbal reports, we can assume that they are expressions of thoughts. The close connection between the ability to report and awareness of one's mental states strongly suggests just what kind of thoughts reports express. Every sincere report of a mental state is an expression of a typically unconscious higher-order thought in virtue of which that very state is conscious.

On the higher-order theory of consciousness, the way that higher-order thoughts describe our mental states determines how those mental states will appear to us consciously. For example, a higher-order thought that describes my sensation as occupying the location of crimson* in the visual quality space, will result in a crimson conscious experience.

This is true not only of the basic qualitative dimensions such as color and sound, but also for complex ones such as space and time. Verbal expressions of the higher-order thoughts in virtue of which sensations are conscious can give us an insight into the way in the higher-order thought describes the sensation. This is precisely why verbal reports play an important role in psychological studies, and can serve as subjective criteria for consciousness.

Higher-order thoughts play a similar role for the intentional states. On the one hand, they describe intentional states as having some intentional content, making them appear consciously as having that very content. On the other hand, they enable reports of those intentional states, the content of which will correspond to the way that the higher-order thought describes the intentional state.

In the case of perceptions, which have both a qualitative and intentional aspect, a verbal expression of a higher-order thought can tell us what the perception appears to be about. It can also inform us about the qualitative character that that perception appears to have to the person we are asking. The sincere report "I taste sweetness" stresses the qualitative character of the perception. In this case, we can find out that the higher-order thought describes the location of the sweetness* mental quality relative to other gustatory mental qualities. And the report "that tastes sweet" stresses the intentional aspect of the perception. In this case, the report tells us that the higher-order thought characterizes the perception as being about something sweet.

The same holds true of reports about temporal perceptions. The sincere report "I saw the red flash occur before the blue flash" expresses a higher-order thought in virtue of which one is conscious of a temporal perception with respect to the location of its timing* quality in the temporal quality space. And the way that the higher-order thought characterizes that perception is reflected in the intentional content of the report.

2.3 Experience Matters

The way in which higher-order thoughts characterize sensations with respect to time partially depends on the conceptual resources of the organism. Without requisite concepts, the higher-order thought cannot describe the sensation in a way that is sensitive to its temporal dimension. But it doesn't take much to have such concepts, and, as we will see, experience with making temporal distinctions facilitates expansion of one's conceptual repertoire for time.

The homomorphism relation between the space of perceptible properties and the corresponding space of mental qualities helps us in creating taxonomies for mental qualities. We start out distinguishing between objects by attributing properties to them. For example, we can say that one paint chip is a lighter shade of blue than another. Mere comparative judgment is enough to pin that shade of blue to a comparative concept: it is the shade of blue that is lighter than that one.

Once a verbal distinction is made, we can extrapolate from concepts that identify those properties to concepts that identify mental qualities. The process is very natural because of the homomorphism relation, which ensures that our mental qualities will be similar and different to each other in a way that reflects the similarities and differences in the perceptible properties. And, finally, if the concepts that identify mental qualities feature in a relevant higher-order thought, then we will be conscious of ourselves as being in a state that features those mental qualities.

Furthermore, the taxonomy of mental qualities usually reflects the conception of the corresponding perceptible properties operative in a particular linguistic community. Visual artists, for example, will have a more fine-grained taxonomy for colors, while musicians will have a more fine-grained taxonomy for sounds. Consequently, the discriminations people tend to make will be reflected in the taxonomies that describe their experiences, and thereby enable them to make more fine-grained reports about their conscious mental states.

The same applies to the taxonomies that characterize conscious experiences of time. The taxonomy of perceptible timing properties helps us extrapolate to a corresponding taxonomy of temporal mental qualities. And the temporal mental quality taxonomy informs the way that higher-order thoughts can describe sensations with respect to time.

As is the case with visual artists or musicians, being called on to make fine-grained temporal discriminations can result in developing a more fine-grained taxonomy. But unlike with colors or sounds, there are few canonical temporal words that can be used in a temporal taxonomy. So, as with size, we add numbers and units and thus end up with descriptions such as “3 hours long” or “shorter than 3 seconds.”

Our temporal taxonomy is not very fine grained. Spatial metaphors such as “before,” “after,” “longer than,” and “shorter than,” typically suffice to describe the temporal dimension of the world. And this simple taxonomy is also reflected in the taxonomy we use for temporal mental qualities. For example, we say that a sensation of red is longer than a sensation of blue and so on.

The influence of language on temporal reasoning is easily explained on the temporal quality space model and the higher-order thought theory of consciousness. In short, the metaphors and concepts used to talk about time in a linguistic community inform the way that higher-order thoughts describe temporal sensations. And, as argued in the previous section, the way that higher-order thoughts describe sensations in turn determines the content of sincere verbally expressed judgments about time.

There is some evidence that strongly suggests that the way that time is linguistically taxonomized in a particular linguistic community influences temporal reasoning and temporal judgments. In one study, Hebrew and English speakers were asked to make timing judgments about scenes depicted in a pair of pictures presented one after the other (Fuhrman and Boroditsky 2010). The results showed that English speakers, who read left to right, make timing judgments more quickly about pictures that depict early-later pairs when they have to use their left hand to press a button indicating their timing judgment. Hebrew speakers, who read right to left, make timing judgments about earlier-later pairs more quickly when they have to use their right hand.

Another study showed that native speakers of Pormpuraaw, who describe time as having an absolute west-east orientation, represent time mentally in a non-relative way (Boroditsky and Gaby 2010). When asked to arrange cards depicting temporally indexed phases of an event, Pompuraawans do not have an interest bias to the right like Americans, but are biased on the east-to-west axis. Furthermore, vertical bias of the same kind has been observed for speakers of Mandarin, who read top-to-bottom (Boroditsky, Fuhrman, and McCormick 2011).

There is more indirect evidence that conceptualization determines experience of time. For one, people are insensitive to duration of unfamiliar stimuli. Duration neglect is ubiquitous and has been demonstrated in a number of studies, especially those involving marketing strategies in business (Ahn, Liu, and Soman 2009). But when information that categorizes the stimulus is available, duration judgments become accurate. In general, cognitive access to information about a stimulus has significant effect on the accuracy of temporal judgments.

In one representative experiment, participants were shown aversive and pleasant film clips of various durations (Fredrickson and Kahneman 1993). The clips were of pigs being killed with clubs, the aftermath of the bombing of Hiroshima, and penguins diving off a glacier, among other pleasant/unpleasant events. During the presentation the participants were asked to use a slider to rank their current experience on a scale from very pleasant to very unpleasant.

After viewing each clip the participants were then asked to rank the overall amount of pleasant or unpleasant experience they had during the clip. They would do so by marking a place on a line that represented a continuum between no pleasure/displeasure and a great deal of pleasure/displeasure. The rankings of overall experience did not significantly correlate with the concurrent rankings recorded during a particular movie clip. These results strongly suggest that the duration of an unpleasant experience has little effect on retrospective judgments of the amount of pleasure/displeasure experienced.

Retrospective duration judgments are generally inaccurate when made out of context. But when more information is available judgments of duration are usually more accurate. This should not be particularly surprising as we expect experience with the duration of a type of event to matter to subsequent judgments. We expect that our knowledge of the duration of a drive from Boston to New York should help in making a judgment about the duration of a drive from Boston to Washington D.C.

The importance of contextual information on duration judgments is not only anecdotal. A series of three experiments shows that comparative information and familiarity with the stimulus has substantial effect on the accuracy of duration judgments (Morewedge et al. 2009). In that study, the first experiment tested the sensitivity of commuters to the duration of a hypothetical commute along familiar and unfamiliar routes. The results indicated that long trips were consistently judged to be less pleasant when they were along familiar routes, but the length of the trip had no effect on judgments of pleasantness of the trip when the route was unfamiliar. In this case, familiarity with the duration meant resulted in more accurate judgments of pleasantness.

In the second experiment, participants were asked to retrospectively evaluate the duration of familiar and unfamiliar sounds as either pleasant or unpleasant. The unfamiliar sounds were harsh synthesizer tones, while the familiar sounds were of a telephone ring. As in the duration neglect study mentioned above, participants misjudged the duration of unfamiliar stimuli regardless of whether they judged them to be pleasant or not.

The third experiment tested whether the sensitivity to the duration of a stimulus changes when the category of the stimulus was made cognitively accessible at the time of judgment. This experiment aimed to determine whether the duration of unfamiliar stimuli is misjudged because the participants' attention was drawn to more salient properties or whether because with unfamiliar stimuli no comparative information is available.

In that experiment, all participants were presented with an unfamiliar sound, which in some cases was labeled as belonging to a category such as "Australian telephone ring." Participants performed consistently better in judging the duration of the unfamiliar stimuli that were labeled. This effect suggests that duration neglect is involves insensitivity to properties of a stimulus that are difficult to evaluate in isolation from other information. Cognitive access to comparative information renders duration judgments more accurate, further supporting the view that temporal experience is determined conceptually.

The role of familiarity with the stimulus likely extends to judgments of timing, as well. For one, familiarity plays an important role in the multi-modal prior entry effect, in which attention affects the accuracy of timing judgments. Reaction times to stimuli are faster when the stimulus is in a modality that the observer expects, i.e., pays attention to (Spence, Shore, and Klein 2001). And temporal order judgments are more accurate when the stimulus is in a modality that the observer expects it to be (Spence, Nicholls, and Driver 2001).

The effect of familiarity on temporal judgments can be easily explained by the temporal quality space model and the higher-order theory of consciousness. With sufficient extrapolation, more precise discriminations lead to more fine-grained descriptions of the temporal aspect of conscious experience. When such descriptions feature in higher-order thoughts, our conscious experiences appear to be temporally more fine-grained.

Also, as with other magnitudes, more contextual information and familiarity often leads to more precise discriminations (Jazayeri and Shadlen 2010). For example, oddball stimuli in a train of familiar stimuli have a longer experienced duration (Tse et al. 2004). The context of familiarity alters the perceived duration of a novel stimulus.

To sum up, higher-order thoughts characterize our sensations with respect to the relative locations of the temporal mental qualities in the temporal mental quality space. And the temporal aspect of conscious experience can be enriched by developing a more fine-grained conceptual repertoire for temporal distinctions. Language acquisition, experience with making discriminations, and comparative information can lead to disparately fine-grained temporal discriminations between the temporal mental qualities one is conscious of. The influence of these factors on the content of higher-order thoughts also helps explain the vagaries of temporal perception noted in the previous chapter—especially since many of those studies relied on the temporal judgments of participants.

3.1.1 When Time Flies Unconsciously

Sensations can misrepresent time by instantiating mental qualities that do not accurately reflect temporal properties. Time flies when we are engaged or enjoy doing something, for example. And time drags when we are bored or wish we were doing something else. Such misrepresentations are fairly common as is suggested by the effects mentioned in this and the previous chapter.

When people say that time flies they usually refer to the conscious experience of time. Still, there is a way to explain these experiences without resorting to the processes of consciousness. Sensory misrepresentation of time—including dilation and expansion of duration—can occur consciously and unconsciously.

The experience of time dragging on can be easily explained on the temporal quality space model. Take as an example a sensation of a two second red flash that appears to be four seconds long. In this case, the sensation of the flash could specify the temporal boundaries of red as being further apart than they were in reality.

For whatever reason, when time drags on, the relations that hold between the timing* qualities are corrupted. Perhaps other processes change the signal, or a processing error occurs. Whatever the cause, the result is a misrepresentation of both timing and duration of the red flash by the sensation such that mental time has stretched out relative to real-world time.

The misrepresentation of the relations between temporal boundaries can also go in the other direction. When the temporal boundaries specified by timing* qualities are closer together than they are in reality, the result is the compression of mental time relative to real-world time. And so goes the explanation of how time flies on the temporal quality space model.

Importantly, this account can be easily extended to cover a range of effects in temporal sensation. Temporal ventriloquism is an example of the timing* qualities failing to correspond to timing properties under influence from audition. And when looming stimuli appear to have longer durations than they actually do that is because sensations of them instantiate temporal boundaries that do not correspond to the actual temporal boundaries of the stimulus.

3.1.2 When Time Flies Consciously

But the temporal quality space model and the higher-order theory of consciousness are two parts of one theory of mental time. The temporal quality space defines the mental qualities that account for the distinct role that temporal representation plays in an organism's life. The higher-order thought theory gives an account of conscious temporal experience.

This two-pronged account of mental time emphasizes the distinct roles of temporal sensations and awareness of those sensations. Both involve representation, albeit of a different kind. Sensations of time represent in virtue of instantiating temporal mental qualities, while higher-order thoughts represent in virtue of instantiating intentional properties.

All representation—including mental representation—can get things wrong about the world. Just as a sentence can be false or a picture can be inaccurate, a belief can be false and a sensation can be inaccurate. Since the sensations of time and the awareness of our sensations of time are both representations of something, there is room for misrepresentation at both levels.

Sensations can misrepresent time by instantiating mental qualities that do not accurately reflect the temporal properties of perceived events. As in the example from the section before this one, a sensation of a two second red flash could specify the temporal boundaries of red as being further apart than they were in reality. The result of this is a misrepresentation of both timing and duration of the red flash.

But even if the sensation specifies the temporal boundaries accurately, there is a way in which it can itself be misrepresented at the level of conscious awareness. The higher-order thought in virtue of which one is aware of the sensation can mischaracterize its location in the temporal quality space. The result would be a conscious experience that does not characterize the sensation accurately.

Disparities between sensations of time and how our awareness of those sensations characterizes them with respect to time are relatively common. Take as an example a conscious experience of something as dragging out in time. In this case, the sensations that instantiate timing* qualities accurately reflect the event's onset and offset and consequently also its duration.

But the higher-order thoughts characterize those sensations' timing* qualities as located further apart in the temporal quality space than they actually are. This is a situation that is importantly different from a misrepresentation of timing discussed in the previous chapter. The misrepresentation is not at the level of sensations, which may actually be representing the timing of the event accurately, but at the level of consciousness.

In this case, the relevant higher-order thoughts also misrepresent the duration* qualities. Timing* qualities are the flanking boundaries of duration* qualities. Consequently, the higher-order thoughts result in conscious experiences of the event as longer than it actually is. The dissonance between the sensations and higher-order thoughts results in time seemingly dragging out.

And of course the situation can be reversed, the higher-order thoughts may misrepresent the relative locations of the timing* qualities instantiated in a sensation as closer than they are. The result would be a distinct kind of experience in which time flies. Again, this kind of experience is fairly common, especially when we are engaged in things we enjoy.

On the views explained here, some temporal illusions are instances of misrepresentation at the level of consciousness. Some, however, are instances of misrepresentation at the level of sensation. The two-part view proposed here distinguishes between the two cases, and also carries with it a methodological recommendation. Researchers interested in mental time should be clear about whether the effect they are describing is caused by sensory processing or whether it is the result of processes of consciousness. Of course, there is also the possibility that an effect has to do with both sensations and consciousness, in which case these components would have to be dissociated.

Purely sensory processing can be dissociated from consciousness behaviorally.

Behavior of a participant can indicate that they are representing the timing and duration of a stimulus accurately. The participant can, for example, tap a button in a way that matches the timing or duration of the stimulus. In such cases, if their verbal reports mischaracterize the stimulus with respect to its temporal properties, then chances are that the effect is the result of awareness misrepresenting the sensation.

Some of the studies cited in the previous chapter may be examples of participants responding to a stimulus in a way that indicates that they are not sensitive to its temporal properties. For example, in the temporal ventriloquism effect, the participants tap their finger in a way that that consistently lags behind the pacing signal (Aschersleben and Bertelson 2003). However, the participants believe themselves to be pacing accurately.

It might be the case that the participants' temporal judgments are the results of corrupted sensory processing. But it could also be the case that the processes responsible for consciousness are disturbed while the sensory processes are left alone. Especially in experiments where the time-scales are small, such as the temporal ventriloquism effect, it may not be clear which case obtains. The view presented here urges that these two possibilities be kept distinct. This leads to what I believe to be an important methodological recommendation for future research.

3.2 Conscious Experience of the Passing of Time Revisited

As mentioned in chapter 2, Sydney Shoemaker has argued that any atomist theory of consciousness, including the higher-order thought theory of consciousness, cannot account for the unity of consciousness over time (Shoemaker 2003). The argument hinges on the claim that the higher-order thought theory implies that experience presents us with a succession of disconnected experiential atoms. This implication violates a phenomenological platitude about our conscious life; our conscious experience appears to be unified and continuous as if it were a stream. So, Shoemaker concludes, the higher-order thought theory should be rejected.

In chapter 2 I highlighted some of the problems with Shoemaker's alternative proposal. Here I will show that the higher-order thought theory does yield a phenomenologically adequate account of the experience of succession. In order to give that account I will specify the way that a higher-order thought characterizes sensations such that they appear to be successive and continuous with each other.

First of all, nothing needs to be added to the temporal quality space model for it to sufficiently explain the way that organisms can sense succession. Every timing* quality will bear relations such as before and after to other timing* qualities. And this ordering will enable the organism to respond differentially to the temporal ordering of events in its environment.

And sensations can occur unconsciously, so succession can be sensed unconsciously. But when sensations are accompanied by a higher-order thought they are conscious and one can then have the experience of succession that Shoemaker, James, and Husserl try to explain. But in virtue of what can the higher-order thought yield a conscious experience of succession?

On the higher-order view, what determines the character of conscious experience is the way that higher-order thoughts describe mental states. So a higher-order thought account of the experience of succession consists in specifying the description that is featured in the content of the higher-order thought. As it turns out, not much has to be added to the existing discussion of conscious experience of time to do this.

Higher-order thoughts in virtue of which temporal sensations are conscious describe these sensations by specifying their relative locations in the temporal quality space. This description specifies the timing* qualities and thereby also the duration* qualities. To add succession to the description, all we need is ordering predicates such as “before x” and “after x” and a quantifier (Quine 1960, p. 172-3). So, on this view, a succession of temporal mental boundaries is sufficient for one to sense succession.

And if the “before” and “after” relations between timing* qualities are sufficient to specify succession, then the higher-order thought also describes the sensation as successive. Presumably, this is usually the case with sensations, since they themselves resemble and differ between each other in such a way as to specify their temporal succession.

But there are some prerequisites that need to be met before a higher-order thought can describe mental states as successive. The possible descriptions are constrained by the conceptual resources available to the organism at the time. If an organism lacks even the most rudimentary concepts, then it could not, on this view, have conscious experience at all. It could not represent itself as having mental states even in the most generic way.

Acquisition of new concepts may enable an organism to have higher-order thoughts that describe mental states in new ways. And, as noted above, language helps here a great deal. Being in a community that operates with a rich taxonomy of colors gives one an advantage with respect to being able to be conscious of the color* qualities of one's sensations in a variety of ways. The same holds for all mental qualities, including timing* and duration* qualities.

Is there such a concept or set of concepts that can figure in the content of a higher-order thought and result in an experience of succession? A good place to look for an answer to this question is the taxonomy we use to describe succession in perceived events. Presumably, given the role that linguistic ability plays in expanding taxonomies of mental qualities, learning to apply the word "successive" to one's conscious experience would be sufficient for one to be aware of it as successive. And having such a concept at one's disposal would enable one to consciously experience that one's sensations are themselves successive.

Learning how to discriminate between events that are successive and not successive and then describe them as such is a prerequisite to having an experience of succession as such. And being able to attribute the property of succession to events enables one to also attribute it to one's sensations. When "successive" figures in the content of a higher-order thought, the mental states so described appear to be successive.

On this view, if a higher-order thought describes one's sensations as successive, then these sensations will appear to one to be successive. And if the higher-order thought does not describe one's sensations as successive, then these sensations will not appear to one to be successive. Either way, the appearance of succession is all there is to the experience of succession.

In sum, the temporal quality space model predicts that the temporal boundaries of these sensations will be represented as being relevantly related to each other. When so described by a higher-order thought, these relations make it into our conscious experience, yielding a conscious experience of succession. And when the higher-order characterizes sensations as successive, we then have an experience of succession.

3.3 Appearance of Unity of Consciousness

The higher-order thought view yields explanations of both kinds of unity associated with consciousness. On the one hand, the higher-order thought theory yields an account of the unity of consciousness important to our sense of self. On the other hand, it yields an account of the sense of unity of conscious experiences distinct from the sense of unity of self. This latter kind of unity is already contained in the account of the experience of succession given above within the framework of the higher-order thought theory

Rosenthal argues that the sense of unity of consciousness as it pertains to a sense of self depends on higher-order thoughts characterizing mental states they are about as belonging to the same self (Rosenthal 2005, p. 342). This characterization is a reference to the person with, roughly, the pronoun “I.” The content of the higher-order thought in virtue of which a mental state is conscious is <I have such-and-such a state>.

On Rosenthal’s view, the “I” in the higher-order thought doesn’t amount to indexical self-reference. If that were so, the pronoun would always refer to the higher-order thought, and not to the individual that has the higher-order thought. So, on this view, the “I” in higher-order thoughts is more like a proper name than an indexical—it will refer to the same person unless something else interferes.

Mere reference to the bearer of the higher-order does not suffice to explain the sense that our conscious experiences all belong to the same person. It could have turned out that distinct higher-order thoughts refer to distinct individuals. And higher-order thoughts are typically themselves unconscious, which means that their reference to the bearer is itself unconscious. Only upon introspection would the reference to the bearer be something of which we would be distinctly aware.

Importantly, higher-order thoughts make us aware of ourselves as having particular mental states. But that isn't where the sense of unity comes from. Rosenthal urges that every “first-person thought thus disposes us to have another thought that identifies the self as the thinker of that very first-person thought” (Rosenthal 2005, p. 343). On this view, the sense of unity is the result of a tacit reference to the thinker of a higher-order thought that consists simply in a disposition to identify that thinker as the bearer of the higher-order thought. The inference is tacit because it is typically unconscious and results in a mere disposition to identify, not an actual identification.

On the higher-order thought view, when we introspect, we have an explicit sense of all of our conscious experiences belonging to the same self. That happens because when we introspect we become aware of a higher-order thought, which refers to the thinker. And we also have an implicit sense of all of our conscious experiences belonging to the same self. The implicit sense of unity is the result of a disposition to have a thought that identifies us as the thinker.

Self-identification can involve many distinct considerations and beliefs.

Sometimes we identify ourselves based on our personal histories, and sometimes by appeal to our personal appearance. Whatever features are involved in a particular self-identification, they will bring to bear a host of past self-identifying thoughts that have successfully secured self-reference in the past (Rosenthal 2005, p. 346). The result will be the same; self-reference based on tacit inference.

The sense of our conscious experiences all being our own, and belonging to a single self is distinct from the sense that they are continuous and unified over time. This is the aspect of conscious experience Hume distinguished from the problem of the unity of the self, and the distinction is, arguably, a good one. Fortunately, the sense of the unity of consciousness as such can also be accounted for on the higher-order thought theory of consciousness. In fact, this has already been done in the account of the experience of succession.

When we consciously sense the duration of an event, the higher-order thought in virtue of which we are conscious of sensing that duration represents the relative temporal distance between the onset and offset of the event. At least this is what happens on the model of temporal experience presented here. Consciously experiencing the duration of an event amounts to having the temporal extension of the event appear to one as such.

Importantly, nothing in this account requires that such unity exists. The mere appearance of unity does not imply actual unity. Higher-order thoughts may characterize mental states in ways that do not reflect their qualitative or intentional properties. As we saw above, this happens frequently with other aspects of temporal perception such as timing and perception.

3.4 Fragmented Reality of Consciousness

We have independent reasons to think that the sensory states of which we are conscious only appear to form a unified stream. The first reason to think so comes from multi-modal perception, which depends on the brain making sense of various kinds of inputs. I argued chapter 3 that this coordination can happen only if multi-modal perception involves modality-specific representations. The second reason for thinking that the conscious appearance of unity does not reflect underlying reality lies in the nature of perceptual processing itself. There is evidence that perception breaks the sensory stream into discrete and unconnected units before passing it onto further processing. I will expand on these reasons in turn.

Multi-modal perception involves a lot of coordination. In humans the various streams of visual, auditory, olfactory, tactile, and gustatory input are processed by independent mechanisms, which, if the argument presented in the previous chapter is sound, involve modality-specific representations. For example, when we look over the Manhattan skyline at night from across the Hudson River, conscious experience presents us with a multi-sensory clutter of sights, sounds, odors, and even tastes.

However, conscious experience presents us with little indication of the coordination that is going on unconsciously. The various features of the Manhattan skyline come together in a single conscious experience that is distinguishable from an experience of any other city skyline in the world. What appears to us in consciousness is a seamless stream of multi-modal experiences of Manhattan that are unified at any moment in time and over time.

At some point information processed by a sensory modality becomes a sensation that instantiates mental qualities. And the sensation itself then informs a perception of a particular sound, sight, or smell of Manhattan. It is only when this process is complete that a single and unified experience of the skyline is possible. And, according to the higher-order thought theory, this experience is conscious when it is accompanied by a higher-order thought about it.

Higher-order thoughts are themselves distinct mental states with determinate content. A higher-order thought about one having a sensation of the Manhattan skyline characterizes that sensation in some particular way. And whatever way the higher-order thought characterizes that sensation will determine the phenomenology of that conscious experience. So, for example, if a higher-order thought characterizes the sensation as being of a checkerboard of windows, a mélange of river odors, and a din of traffic, those are the qualities that will appear to one in experience.

Each higher-order thought is a distinct mental state. And each higher-order thought occurs some time after the preceding higher-order thought. So the succession of our conscious experiences is actually a succession of distinct and determinate mental characterizations. In between every new conscious experience passes a period of time during which the characterization continues to inform conscious appearance or disappears to be replaced by another. The higher-order thought view is thereby thoroughly atomist.

The train of discrete conscious appearances presented to us by the descriptions in higher-order thoughts is accompanied by the experience of succession. This sense of the passing of time renders the train of discrete conscious appearances as a train of fluid and connected conscious appearances. Consequently, the underlying atomist reality of consciousness never makes it into our phenomenology.

Consciousness does not form a continuous stream that resembles the seamless sequence of events that unfolds on the stadium pitch. On the contrary, neural activations relevant to it are spatially and temporally distributed between distinct sensory systems. And the modality-specific temporal representations of these events function independently of each other until they are needed in the process of coordination.

4.1 The Lingering Objection: Hume and Husserl[11]

The first way to resist the view that we consciously perceive time in the way that my view suggests is to reject it on phenomenological grounds. We cannot be aware of temporal relations to past experiences because that implies that our conscious experiences are very different from the way they appear to be. Namely, they would appear to linger on, like echoes or visual trails.

On the heels of appeals to phenomenology come alternative views that seemingly sit more comfortably with the phenomenology. Many of these views are problematic for reasons that I have outlined in Chapter 2. In the case of conscious experience of time, these alternatives typically urge that we do something other than

[11] In the interest of clarity, much of the discussion of Hume and Husserl is lifted from Chapter 2 of this dissertation. Parts of Chapter 1 are used to revisit problems for the kind of view of temporality advanced here.

perceive time. We infer, think, believe things about time, but we do not perceive it. I will first diffuse this phenomenological objection and then move on to assess some of these alternatives.

According to the view offered here, we perceive duration in virtue of the relations that timing qualities bear to other timing qualities. And conscious experience of duration, that is, the conscious experience of temporal extension, involves us being aware of these relations as such. Consequently, when we have a conscious experience of duration we experience a number of relations to other experiences that came before it.

However, the objection goes, if past perceptions featured in our conscious experiences in any way, then our experiences would be crowded with lingering auditory echoes, visual trails, and so on. Under normal conditions, we do not have such experiences, so it must be false that the experience of temporal extension is in any way qualitative. I think this sort of objection misses the mark.

The temporal quality model does not imply lingering qualities, even though other perceptual accounts might. According to the view I sketched above, it is our awareness of the relations between temporal qualities that is responsible for the experience of temporal extension. These relations are not themselves the sounds*, colors*, and so on that we experienced in the past—they are relations that hold between them. We do not have to be aware of the relata to be aware of the relation.

Take, for example, some iron chips on a piece of paper. If one puts a magnet on the underside of the paper, and then moves the magnet around, the iron chips will move with the magnet. If one is not aware of the magnet in any way, one will still perceive the iron chips as being moved by something, even though it might not be clear by what.

The same holds for the relations between temporal mental qualities. When one perceives the onset of a C, which came after the B, the B itself—just like the hidden magnet—is not perceived in any way. But the C is perceived as related (by the 'after' relation) to the B, just as the iron chips are perceived as related to something that moves them (the magnet's attractive field).

Given this, the sounds* and colors*, and so on, that were features in our past conscious experiences need not figure in our conscious experience of temporal extension right now. This is because what underlies an experience of temporal extension are the temporal relations that we are aware of in the present. The sensory qualities that feature in our conscious experience in the present are enough to give us relations to the past, as with a hidden magnet. We have no reason to think that qualities of past conscious experiences linger, so the phenomenological objection is diffused.

What about the alternative views? One possibility is that we believe or infer things about time, but we do not perceive it. This line of thinking finds its origin in David Hume, who suggested that "as 'tis from the disposition of visible and tangible objects we receive the idea of space, so from the succession of ideas and impressions we form the idea of time" (Hume 2000/1739, p. 35). On Hume's view, we are disposed to infer the experience of temporal extension from the succession of experiences. Hume uses a similar explanation in his celebrated theory of cause and effect.

But, contrary to Hume, there is at least one good reason to think that we do not simply infer the idea of time. Evidence against this view can be found in motion blindness, or akinetopisia, as this condition is sometimes called. Motion blindness is an extremely rare disorder caused by the malfunction or lesion of area V5 (MT) in the visual cortex. This area of the brain has been identified as crucial to processing visual information about motion (Zeki 2004, 1991; Beckers and Zeki 1995).

Motion blindness causes one to have experiences that are a series of disconnected stills. What is functionally impaired in people with V5 (MT) damage is their ability to discriminate the timing of the onset and offset of properties in the world altering their perception of motion. Their temporal discriminations are very coarse-grained. Consequently, it becomes near impossible for them to perceive the duration of things.

This suggests that damage to the visual system, and specifically to area V5 (MT), causes deficits in the accurate perception of the duration of events. But, importantly, area V5 (MT) is not directly involved in inferential reasoning—it is a dedicated part of the visual system. So, a person affected by motion blindness, if they are not also cognitively impaired, can perform a range of inferences.

Presumably, they can also form beliefs that the succession of their still experiences corresponds to a succession of the things they perceive in the world. A still of an object at one position, followed by a still of the same object at another position is, all things being equal, enough to infer that the object moved. Nonetheless, they do not thereby gain the ability to experience duration in the way that we do.

So, even though the motion-blind can make the kind of inferences that Hume describes, they cannot perceive duration in the way that we do. And it seems that the reason they cannot is connected to their perceptual deficit. It is therefore safe to think that Hume was wrong about the experience of time being constructed out of an inference.

Another popular alternative proposal to the perceptual story is Edmund Husserl's later theory of time consciousness. Husserl thinks that we perceive things as extended in time because of the structure of conscious experience, not in virtue of any of its contents. On this view, experiences have a tri-partite structure, where what Husserl calls retention is the part that holds the content of just-past experiences, protention holds the contents of perceptions one is about to have, and primal impression holds the now.

In Husserl's own words, "when a primal datum, a new phase, emerges, the preceding phase does not vanish but is 'kept in grip' (that is to say, precisely 'retained')" (Husserl 1991/1917, p. 118). On this view, the just-had experience remains a part of a conscious experience and continues to influence following experiences. Protentions, on the other hand, influence the conscious experience we are about to have "the preceding protention intentionally contains all the later in itself (implies them); the succeeding retention intentionally implies all the earlier ones" (Mensch 2003, p. 71f4; translation of Husserl's manuscript L I 16, p. 6a).

The notion of intentional containment is important, albeit confusing. It is important in the present context because it differentiates Husserl's view from the view that we simply retain conscious experiences. The latter kind of view would come under attack from the phenomenological challenge of lingering qualities I mentioned in the beginning of this section. But that in itself does not say much about what intentional containment is.

Shaun Gallagher sheds light on the role of intentionality in Husserl's theory in the following way: "Retention, according to [Husserl's] later theory, does not retain real contents; it retains intentional contents. It retains the sense (the meaning content) of what has just consciously passed (…) retention is not something that is apprehended; it is a part of the structure of apprehending, if by that we mean awareness" (Gallagher 2003). What this suggests is that past experiences are more like thoughts than perceptions. Intentional containment involves intentional contents about the past.

But each of the parts of a single conscious experience—retention, protention and primal impression—are not just thoughts. That would be like having two thoughts and a perception simultaneously, which on its own would not be enough. As mentioned in the discussion of Hume above, merely thinking about the past is not sufficient to have an experience of temporal extension. So there must more to intentional containment than just intentional content.

Indeed, Husserl conceives of retentions as containing the full tri-partite structure of the past experience. The different parts of the retention-primal impression-protension sandwich are structural features that comprise every conscious experience.

> In this way, it becomes evident that concrete perception as original consciousness (original givenness) of a temporally extended object is structured internally as itself a streaming system of momentary perceptions (so-called primal impressions). But each such momentary perception is the nuclear phase of a continuity, a continuity of momentary gradated retentions on the one side, and a horizon of what is coming on the other side: a horizon of "protention,"

> which is disclosed to be characterized as a constantly gradated coming (Zahavi 1999, p. 54; translation of Husserl's manuscript IX, 202 in Husserl-Archive).

This recursive structure of the retention-primal impression-protention sandwich then forms an intentional horizon of our conscious experience. But how does it do that?

Dan Zahavi explains: "The relations between protention, primal impression, and retention are not relations among items located within the temporal flow; rather these relations constitute the flow in question" (Zahavi 2007, p. 468). Zahavi's point is that the intentional relations are not merely contents of conscious experiences, but something more like vehicles of those conscious experiences. On this view, there are no lingering colors and sounds in present experience because past conscious experiences are present as structural parts of the conscious experience we having right now.

One virtue of this view is that, unlike Hume's, it addresses the problem of how we perceive duration. Husserl's answer is that we perceive duration because of the tri-partite structure of conscious experience. This view can also explain why we hear the C at the end of A-B-C as different from a single C. In short, in the first case, the A and the B are a part of the structure of the conscious perception of C while in the second case they are not.

However, the disadvantage of the view is that it involves a lot of conceptual machinery that we are given little independent reason to accept. As Sean Kelly puts it, with Husserl's view "we have no interesting account of what it is now to experience something *as just-having-been*, except to say that it is the phenomenon involved in the experience of the passage of time. But this is the phenomenon we are trying to *explain*. It does no good just to give a name to its various parts" (Kelly 2005, p. 226). Kelly's point here is that protentions, retentions, and primal impressions are just names for the temporal features of perception we want to explain. They are not themselves the explenans.

And why should we suppose that consciousness is constituted by retention, protention and primal impression to begin with? There seems to be no way to verify Husserl's theory empirically, since the structure that Husserl attributes to conscious experience is merely intentional. There are some attempts to make the connection between Husserl's views and empirical hypotheses (Lloyd 2011; Varela 1999). But whether these are successful is contentious (Lee 2012; Klincewicz 2012; Grush 2006)

In this section I argued that the temporal quality model can resolve the phenomenological objection of lingering qualities. Also, I argued that historically important alternatives to the view that we perceive time are problematic.[12] Given the mentioned disadvantages of these alternatives we have a reason to adopt some version of a perceptual account.

However, the temporal qualities model has to answer another objection. This one pertains specifically to the account of conscious experience of temporal extension based on the temporal qualities model.

4.2 The Unity Objection

Temporal quality model of temporality is atomist and some object that this violates the manifest unity of consciousness (Bayne 2010; Shoemaker 2003; Bayne and

[12] Chapter 2 contains a more exhaustive list of alternatives and their problems.

Chalmers 2003). The source of the objection is an observation that conscious experiences appear to us as seamlessly unified at a time and over time, that is, as parts of a stream of consciousness. As William James famously said "consciousness (…) does not appear to itself chopped up in bits. (…) It is nothing jointed: it flows. A 'river' or a 'stream' are the metaphors by which it is most naturally described" (James 1890, p. 233). This unified flow is a feature of conscious experience if anything is.

However, the temporal quality model is atomist in that it suggests that each conscious experience is a phenomenological atom independent of other such atoms that come before or after it. One atom after another is not the same as a seamless stream. So, the temporal quality view is incompatible with the apparent unity of conscious experience and should be rejected.

One possible response to this challenge is to urge that the phenomenology of a stream is misleading (Tye 2009, p. 155-82; Clark 2002; Blackmore 2002; Dennett 1991; O'Regan 1998, 1992). A typical way of developing this line of thinking is to stress that the apparent plenum of consciousness is the result of a version of the refrigerator light illusion. We assume that the light of consciousness never goes off, because every time we access it is on. In reality, however, conscious experience never extends beyond our limited access—just like the light in the refrigerator never stays on except when we open the door.

Daniel Dennett's way of developing this argument is paradigmatic, so I will rehearse it here. Imagine you walk into a room papered over with a wallpaper pattern of identical Marilyn Monroe portraits. Normally, you will see the wall as papered over with identical portraits of Marilyn as soon as we walk into the room.

The Marilyns become a part of our conscious experience so fast that we cannot assume that the visual system processes them one at a time; there must be a short-cut. One possibility is that the brain renders the Marilyn portraits in a copy-and-paste fashion, perhaps sampling one patch and then filing in the rest with it. But that story is highly unlikely.

Our brain does not have the computational resources to accomplish this task during the first glance at the wall. And why should our brain do this even if it did have them? And this is where the final alternative becomes apparent.

When we consciously experience the Marilyn wallpaper, Dennett urges, we see some small part of it in our fovea and then our brain "jumps to the conclusion that the rest are Marilyns, and labels the whole region 'more Marilyns' without any further rendering of Marilyn at all" (Dennett 1991, p. 355). Unless the brain receives information to the contrary, it generalizes and make our perceptual system ignore the rest of the wall. This is the most economical and thus most plausible explanation of how we see the wall as papered over with Marilyns so quickly.

Of course, it does not seem that way to us. Our phenomenology seems to us to be a plenum full of identical Marilyn portraits, all unified into one conscious experience. But that is because whatever we are aware of at any given moment exhausts our phenomenology. We assume that there is more phenomenology available, even though it is not there at all, in any sense.

Whatever our brain labels as 'more Marilyns' does not make it into our consciousness at all except in that generic form. Consequently, just as with the refrigerator light, we make an inference to the best explanation. And this squares with the way that people typically describe the unity of their conscious experience, namely, as having a sharply focused center and an indistinct periphery.

Does the refrigerator light response apply to the unity of consciousness over time? Let us come back to the example of the melody. When we consciously hear the C at the end of A-B-C, our conscious experience is different from that of a C that follows nothing. Or at least so it seems.

The temporal version of the refrigerator light story might go something like the following. The A and B only seem to be a part of our conscious experience of the C at the end of A-B-C. In reality, the mental qualities of A and B do not feature in conscious experience of the C at all. At best, they are labeled by the brain in a generic way, perhaps as 'the sounds that just passed.' Arguably, Dennett himself offers something to this effect in his representationalist account of the color-phi phenomena (Dennett and Kinsbourne 1997).

There is at least one reason to think that it is not the case. If the temporal version of the refrigerator light story is true, then we would have no way of making the conscious discrimination between a melody and series of random sounds. Music appreciation, if it was even possible, would have little to do with hearing the music.

Sydney Shoemaker makes the point in the following way: "it is essential to the awareness of the melody as *that* melody (…) that one be aware of the relationship between the different notes (…). And this requires unity of consciousness—the co-consciousness of the experiences of the different notes [over time]" (Shoemaker 2003, p. 65; Shoemaker's italics). It is these relationships between the notes that make the conscious experience of the melody what it is. And that seems right: we hear music even if we do not know how to think about it.

Bracketing what co-consciousness amounts to, Shoemaker's point is that perceiving temporal extension is essential to the task of individuating different melodies. Normally, we can discriminate an experience of A-B-C from an experience of B-A-C. However, if the temporal ordering of A* and B* make no auditory difference to how we consciously experience the C*, as the temporal version of the refrigerator light story would seem to suggest our conscious experience of the C would be the same in either case.

The temporal version of the refrigerator light story gets rid of the contribution that conscious experiences make to the present. And that leaves mysterious how we distinguish between different melodies. But, as Shoemaker observes, we can and do make such discriminations perceptually. Arguably, we can make them even without having any notion of notes, music, and so on.

So, the refrigerator light story might be correct, but only for the qualitative contents of past conscious experience, such as sounds, colors, and so on. It has to be wrong, however, about the specific contents of past conscious experiences having no relevance to the present altogether. The past features in the present in a way that makes a qualitative difference, without being present in the way it was when it was the present.

However, past conscious experiences are still beyond the kind of access that we have to the contents of present conscious experiences. So, on the one hand, our conscious past contributes to the qualities of the conscious present, but, on the other, it is out of reach. Inspired by Ned Blocks's distinction between phenomenal and access consciousness, one may think that this is an instance of phenomenal consciousness that extends beyond access consciousness in a kind of phenomenal overflow (Block 2011).

Much has been said about whether consciousness extends beyond access in the way that Block suggests and it is beyond the scope of this paper to address it here (Brown 2012; Cohen and Dennett 2011; Kouider et al. 2010). I mention the distinction between phenomenal and access consciousness only to point out that nothing in the temporal qualities model depends on the existence of phenomenal overflow. We do not need to accept Block's distinction in order to go along with the model of temporality I offer here. Even though the temporal version of the refrigerator light story does not cover everything, this does not mean that Block's distinction is the answer.

This is because the temporal qualities and the relations they bear to other qualities of the same kind are instantiated in a single perception. Being aware of that one perception in an appropriate way results in the kind of phenomenology we associate with temporal extension. When we are aware of the temporal qualities instantiated in the perception our conscious experience will feature these qualities—nothing is left out.

Conscious experience of temporality can result from us being aware of just one perception. In Block's terms, we need be access conscious of just one perception to experience it as extended in time. All we need is to be aware of are the temporal qualities featured in the perception.

So, coming back to the unity objection, our phenomenology squares with James' characterization of the flow. But we need not take this appearance to reflect reality. Conscious experiences can themselves be "chopped up in bits" and not flow, as James and others suggest. Rather, they are momentary snapshots, albeit indistinct and incomplete ones, which are related to other such snapshots via their temporal qualities.

The temporal quality model implies that individual conscious experiences appear unified over time by the temporal relations that obtain between individual temporal qualities. Time appears to pass because we are aware of mental qualities as related to each other in an appropriate way. And our conscious experiences appear unified because of the temporal relations that hold between them.

5 Conclusion

I argued that the conscious experience of unity over time that is a celebrated part of both philosophy and art is the result of us being appropriately aware the temporal relations between mental qualities, such as color*, sound*, and so on. When we hear a melody, the past notes contribute to our conscious experience by bearing those relations to the auditory qualities we featured in our phenomenology at that time.

This view can answer the phenomenological challenge of lingering mental qualities. It is also superior to alternative views based on intentional content or belief. Finally, I argued that the perceptual account of temporality offered here sits comfortably with the manifest unity of consciousness over time.

APPENDIX

```
void SystemClass::makeThresholdList(float average) {

 for ( int x = stimulus1Durations.Count(); x > 0; x-- ) {
  stimulus1Durations.Delete( x );
 }

 float temp;
 average = average + 330;

 for ( int y = 0; y < 20; y++ ){
  probType *item;
  item = new probType;
  average = average - 30;
  item->data = average;
  stimulus1Durations.Add( item );
 }
}


void SystemClass::makeStimulus1List() {

 ofstream debugFile;
 debugFile.open("../Engine/experiment_data/debug.txt", ios::app);

 probType *item;
item = new probType;
 item->data = range;
 stimulus1Durations.Add(item);

 for ( int x = 0; x < 30; x++) {
   probType *item;
   item = new probType;
   item->data = ( stimulus1Durations.Retrieve(stimulus1Durations.Count())->data / slope
);
   stimulus1Durations.Add(item);
 }

 debugFile << "slope: " << slope << " " << range << endl;

}

void SystemClass::makeStimulus2List(int blocks) {

 probType *item;
```

```
 item = new probType;
 item->data = range / 2;
 stimulus2Durations.Add(item);

 for (int x = 0; x < blocks; x++){
  probType *item;
  item = new probType;
  item->data = stimulus2Durations.Retrieve(stimulus2Durations.Count())->data / 1.5;
  stimulus2Durations.Add(item);
 }
}

bool SystemClass::Threshold(){

 ofstream tDebug;
 tDebug.open( "../Engine/experiment_data/debugThresholds.txt", ios::app);
 tDebug << "S: " << subjectId << " T: " << trialTracker << " | ";

 switch ( thresholds.Count() ){

  case 0:
   if ( lastResponse == FIRST ){
    tDebug << "first stimulus." << listTracker << " " << stimulus1Durations.Retrieve(
listTracker )->data << endl;
    listTracker++;
    lastLastResponse = lastResponse;
    return false;
   }
   else if ( lastResponse == SECOND ) {  // first crossover
    tDebug << "first crossover event." << listTracker << " " <<
stimulus1Durations.Retrieve( listTracker )->data << endl;
    probType *item1 = new probType;
    item1->data = stimulus1Durations.Retrieve( listTracker )->data;
    thresholds.Add( item1 );
    //stimulus1Durations.Retrieve( listTracker );
    listTracker++;
    lastLastResponse = lastResponse;
    return false;
   }

  case 1:
    if ( lastResponse == SECOND && counter != 2 ){  // 1st threshold not yet correct
     tDebug << "first threshold checking." << listTracker << " " <<
stimulus1Durations.Retrieve( listTracker )->data << endl;
     counter++;
```

```
      //stimulus1Durations.Retrieve( listTracker );
      lastLastResponse = lastResponse;
      listTracker++;

      return false;
     }
     else if ( lastResponse == SECOND && counter == 2 ) {  // first threshold correct
       //stimulus1Durations.Retrieve( listTracker );
       listTracker--;
       lastLastResponse = lastResponse;
       tDebug << "first threshold correct event. Tracker=" << listTracker << " " <<
stimulus1Durations.Retrieve( listTracker )->data << endl;
       return false;
     }
     else if ( (lastResponse == FIRST) && (counter != 2) ) {  // first threshold incorrect
      tDebug << "first threshold incorrect event." << listTracker << " " <<
stimulus1Durations.Retrieve( listTracker )->data << endl;
      counter = 0;
      thresholds.Delete(thresholds.Count());
      lastResponse = lastLastResponse;
      listTracker = listTracker - counter;

      return false;
     }
     else if ( (lastResponse == FIRST) && (counter == 2) ) {  // second crossover
      tDebug << "second crossover event." << listTracker << " " <<
stimulus1Durations.Retrieve( listTracker )->data << endl;
      counter = 0;
      probType *item2 = new probType;
      item2->data = stimulus1Durations.Retrieve( listTracker )->data;
      thresholds.Add( item2 );
      listTracker--;
      lastLastResponse = lastResponse;

      return false;
     }

   case 2:
     if ( lastResponse == FIRST && counter != 2 ) { // not yet verified threshold
      tDebug << "checking second threshold." << listTracker << " " <<
stimulus1Durations.Retrieve( listTracker )->data << endl;
      counter++;
      listTracker--;
      lastLastResponse = lastResponse;
      return false;
     }
```

```
    if ( lastResponse == FIRST && counter == 2 ) { // verified second threshold
     tDebug << "verified second threshold." << listTracker << " " <<
stimulus1Durations.Retrieve( listTracker )->data << endl;
     listTracker++;
     lastLastResponse = lastResponse;
     return false;
    }
    else if ( (lastResponse == SECOND) && (counter != 2) ) {  // second threshold
incorrect
     tDebug << "second threshold incorrect event." << listTracker << " " <<
stimulus1Durations.Retrieve( listTracker )->data << endl;
     counter = 0;
     thresholds.Delete(thresholds.Count());
     lastResponse = lastLastResponse;
     listTracker = listTracker+counter;

     return false;
    }
    else if ( (lastResponse == SECOND) && (counter == 2) ) {  // third crossover
      tDebug << "third crossover event." << listTracker << " " <<
stimulus1Durations.Retrieve( listTracker )->data << endl;
      probType *item3 = new probType;
      item3->data = stimulus1Durations.Retrieve( listTracker )->data;
      thresholds.Add( item3 );
      listTracker++;
      counter = 0;
      lastLastResponse = lastResponse;
      return false;
    }

  case 3:
    if ( lastResponse == SECOND && counter != 2 ){ // not yet verified third threshold
     tDebug << "verifying third threshold." << listTracker << " " <<
stimulus1Durations.Retrieve( listTracker )->data << endl;
     listTracker++;
     counter++;
     lastLastResponse = lastResponse;
     return false;
    }
    else if (lastResponse == SECOND && counter == 2 ) { // verified third threshold
     tDebug << "third threshold correct." << listTracker << " " <<
stimulus1Durations.Retrieve( listTracker )->data << endl;
     listTracker--;
     lastLastResponse = lastResponse;
     return false;
    }
```

```
      else if ( lastResponse == FIRST && counter != 2 ) { // error setting threshold
       tDebug << "error verifying third threshold." << listTracker << " " <<
stimulus1Durations.Retrieve( listTracker )->data << endl;
       listTracker = listTracker - counter;
       counter = 0;
       lastLastResponse = lastResponse;
       thresholds.Delete( thresholds.Count() );
       return false;
      }
      else if ( lastResponse == FIRST && counter == 2) {  // fourth crossover event
       tDebug << "third threshold correct." << listTracker << " " <<
stimulus1Durations.Retrieve( listTracker )->data << endl;
       probType *item4 = new probType;
       item4->data = stimulus1Durations.Retrieve( listTracker )->data;
       thresholds.Add( item4 );
       lastLastResponse = lastResponse;
       listTracker--;
       counter=0;
       return false;
      }
    case 4:
     if ( lastResponse == FIRST && counter != 2 ){ // not yet verified fourth threshold
       tDebug << "verifying 4th threshold." << listTracker << " " <<
stimulus1Durations.Retrieve( listTracker )->data << endl;
       listTracker--;
       counter++;
       lastLastResponse = lastResponse;
     }
     else if ( lastResponse == FIRST && counter == 2 ){ //verified fourth threshold (DONE)
       thresholdBlock *t = new thresholdBlock();
       probListClass *pC = new probListClass();

       float tempHolder;
       float averageHolder = 0;

       for ( int x = 0; x < thresholds.Count(); x++ ) {
         tDebug << "thresholds.Count: " << x;
         probType *item;
         item = new probType;
         tempHolder = thresholds.Retrieve(x)->data;
         averageHolder = averageHolder + tempHolder;
         item->data = tempHolder;
         pC->Add(item);
       }

       averageHolder = averageHolder / thresholds.Count();
```

```
      averageThreshold = averageHolder;

      allDone = true;

      t->data = pC;
      tList.Add(t);

      for ( int a = thresholds.Count(); a > 0; a-- ) {
       thresholds.Delete(a);
      }

      listTracker=0;
      counter=0;
      return false;
    }
    else if ( lastResponse == SECOND && counter != 2 ) { // error verifying threshold
      tDebug << "error verifying 4th threshold." << listTracker << " " << stimulus1Durations.Retrieve( listTracker )->data << endl;
      listTracker = listTracker + counter;
      counter = 0;
      lastLastResponse = lastResponse;
      thresholds.Delete( thresholds.Count() );
      return false;
    }
    else if ( lastResponse == SECOND && counter == 2 ) { // fifth crossover (DONE)
     thresholdBlock *t = new thresholdBlock();
      probListClass *pC = new probListClass();

      float tempHolder;
      float averageHolder = 0;

      for ( int x = 0; x < thresholds.Count(); x++ ) {
        tDebug << "thresholds.Count: " << x;
        probType *item;
        item = new probType;
        tempHolder = thresholds.Retrieve(x)->data;
        averageHolder = averageHolder + tempHolder;
        item->data = tempHolder;
        pC->Add(item);
      }

      averageHolder = averageHolder / thresholds.Count();
      averageThreshold = averageHolder;

      allDone = true;
```

```
      t->data = pC;
      tList.Add(t);

      for ( int a = thresholds.Count(); a > 0; a-- ) {
       thresholds.Delete(a);
      }

      listTracker=0;
      counter=0;
      return false;
    }
  }
  return true;
}
```

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