

Subjective Duration

Geoffrey Lee

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1. Introduction

Anyone who has viewed a slow-motion replay or a movie created using time-lapse photography is familiar with high-speed or slow-motion experiences of events. Such experiences are an eerie counterpoint to our ordinary perceptual awareness of events playing out in time, both because familiar processes are presented at an abnormal rate, but also because processes and temporal patterns that would otherwise be invisible come to light. In the case of time-lapse movie of, say, the growth of a plant or fungus, not only are we presented with events as changing much faster than they really are, but we become directly aware of otherwise unperceivable temporal patterns, such as the plants shooting towards the sunlight, or wrapping their tendrils around another object for support. Or in slow-motion, we might perceive the flapping of a hummingbird's wings, a process far too rapid to perceive in real time, given the limited temporal resolution of the human visual system.

It doesn't take a huge leap of the imagination to suppose that individuals might have such experiences of the world in their normal state. After all, our capacity to experience temporal relations presumably evolved to make us perceptually sensitive to environmental changes over a fairly limited range of durations and temporal frequencies that are relevant for our idiosyncratic purposes. Other creatures with different perceptual needs might be specialized to perceive a quite different range of temporal phenomena, perhaps meaning that they are permanently enveloped in an experiential world where everything changes far more slowly or quickly than in the world of human perception. Perhaps a hummingbird's experience of an object moving rapidly through the visual field is like the experience you would have of an object moving far more slowly through the same trajectory; or perhaps unlike you they would be unable to experience it all, in much the way you are unable to perceive the motion of a speeding bullet or the stars in the night sky. In this way there might be systematic variation in the subjective rate of time's passage that is normal for different individuals.

A more localized form of variation may happen within the conscious experience of ordinary individuals. This is illustrated by the existence of temporal illusions that have been shown to be induced by certain stimuli (see Eagleman (2008) for a review of recent examples in the empirical literature). For example, in the "oddball" effect a subject is presented with a series of identical, equally spaced stimuli of a certain fixed duration that are interrupted by an "oddball" with saliently different features – e.g. it is larger, a different shape, or it is moving (see e.g. Tse et al (2004)). The oddball objectively lasts the same amount of time as the other stimuli, but vividly appears to last longer. Such cases seem to involve a transient stretching or dilating of experience of a kind that we are imagining happening more globally in the cases just described.

My interest here is not in whether such variation in subjective rate of passage – whether transient or global - is really possible (although I think it is), but rather in what it would consist in were it possible. We might think that we need to appeal to a distinction between objective duration and subjective duration to make sense of these cases. But what exactly is subjective duration? A tempting idea is that temporally extended portions of the stream of consciousness have a property we might call “phenomenal duration” that in some sense provides a measure of how long an experience “feels” to its subject, and that different rates of passage consist in the stream of experience flowing at different rates through the window of awareness, as measured by this subjective metric. A transient duration illusion would consist in a literal warping of the fabric of consciousness, a portion of your experience having a longer subjective duration than it should, resulting in an illusory presentation of the duration of some external event.

My main contention in this paper is that there is no such thing as “phenomenal duration” in this sense. Thinking about why this is will help us get in view a better picture of subjective duration. More specifically, I will be arguing against what I’ll call the “Phenomenal Metric view”¹. On this view experiences are arranged in phenomenal time, meaning they have a property “phenomenal duration”, which has the following features:

- (1) It is a phenomenal property – it is an aspect of what it is like to have an experience.
- (2) It belongs to temporally extended chunks of the stream of consciousness.
- (3) It provides, at least roughly, a metric on the stream.
- (4) It has to do with how long an experience feels to a subject.

I will argue that there is no such property: although it is possible to make sense of different subjective rates of passage, this should not be understood in terms of experience flowing at different rates as measured by an intrinsic phenomenal metric. I will argue for an alternative conception which I call the *Retrospective View*. On this view, the closest thing temporally extended experiences have to phenomenal duration is an extrinsic response-dependent property I’ll call “retrospective apparent duration”: roughly, how long the experience seems to have lasted retrospectively.

Although I think this is the correct view, I also think that accepting it may require giving up some deeply held intuitions about experience and time that I will attempt to articulate. In particular, our normative views about the values of different experiences require being able to measure *quantities* of experience like pleasure and pain; if there is no phenomenal metric this becomes problematic, for reasons I will explain. This means that the points I will make should be of interest not just to those interested in the mind, but also to those constructing normative theories in ethics, economics and other areas concerned with measuring human welfare.

¹ See Dainton (2010) for an explicit endorsement of the view, or something close to it. To my knowledge, the only other place the issue gets explicitly discussed is Pariyadath and Eagleman (2007, 2009), who also argue against something like the Phenomenal Metric view.

2. Some different notions of Subjective Duration

Let's begin by looking a little more carefully at some different ways of precisifying the idea of "subjective duration". The least controversial sense in which there is a difference between objective and subjective duration comes from the possibility of duration illusions, such as the one involved in the Oddball effect. In this case there is a difference between the *objective duration* of an event and its *apparent objective duration*.

Arguably not every subjective difference in temporal experience can be captured in terms of this distinction however, because of the possibility of systematic differences in temporal experience between organisms in their normal state. If a one second stimulus has a different phenomenology for me and a hummingbird, and a similar difference exists in a systematic way for other perceivable durations and rates of change, it's not clear that this requires that one of us is systematically misperceiving. Neither of our perceptual apparatuses need in any way be malfunctioning. To make this slightly more precise, suppose we have two subjects Quickly and Slowly who differ in this way: in their normal states, what it is like for Slowly to experience a stimulus of duration t , is what it is like for Quickly to experience a stimulus of duration $2t$ (provided such a stimulus is within Quickly's perceptual range), and similarly for experiences of other duration-dependent phenomena like rates of change. Roughly, Quickly's experiences are like those that Slowly would have, were everything changing twice as quickly as it actually changes. If such variation in "subjective rate of passage" can occur, how is it best understood? The first point to make is that it motivates a further sense in which there are subjective features of experience associated with duration perception, beyond the simple apparent / objective duration distinction, because the phenomenology of accurately perceiving a certain duration may vary between individuals like Quickly and Slowly. We can call such phenomenal properties the "phenomenology of duration experience".

What are these phenomenal properties, if they exist? What exactly is the difference between subjects like Quickly and Slowly? We shouldn't automatically assume that if such phenomenal properties exist, this is incompatible with an intentionalist treatment of duration experience, on which the phenomenal character of perceptual experience is fully constituted by the way the scene around the subject would be arranged, were the experience veridical – a proposition, or a complex property. The case of Quickly and Slowly suggests that the phenomenology of duration experience is not fixed by the apparent objective duration of events, but there are other possibilities consistent with Intentionalism, such as the view that this phenomenology is fixed by the experience of *relations* between the objective durations of external events and the duration and rates of change of internal processes in the brain. An analogy might be spatial experience; one plausible view is that we experience *relations* between the sizes of external objects and the size of our body or body parts, rather than experiencing size in a more absolute sense. Similarly, if Slowly's internal clock, or other processes related to measuring time, are running systematically faster than Quickly's, then they might differ in the relational temporal properties they can accurately represent external events as having.

The idea that experience has a relational content such as this deserves extended discussion, both in the spatial and temporal cases, but it is not my goal to have that discussion here. Instead I want to focus on the idea this duration phenomenology should

be thought of in terms of a phenomenal metric – the Phenomenal Metric view (which may be consistent with the view that experience has relational duration content). A proponent of the existence of a phenomenal duration metric on the stream will naturally propose that the phenomenal difference between Quickly and Slowly consists in their experiences flowing at different phenomenal rates, and therefore that the phenomenology of duration experience can be reduced to phenomenal duration: on this view, the reason why an external event appears to unfold more quickly for Quickly is that her experience of it unfolds more quickly.

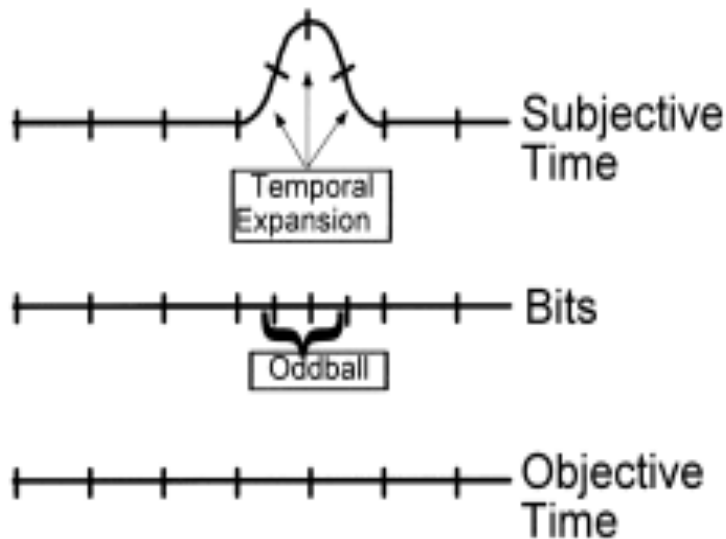


Fig 1. Subjective and Objective Time, as conceived by Tse et al. (2004).

The idea is illustrated in the above diagram from Tse et al. (2004) discussing the oddball effect. During the illusion, experience is packed more densely in time, as measured by the subjective metric (it is not clear whether Tse et al. think of “subjective time” as having all the features of phenomenal duration, however).

On Tse et al.’s view, subjective time is realized by the rate of information processing underlying experience, as illustrated in the central part of this diagram. This is an example of a tendency to think that there is constitutive connection between the rate of flow of experience, and the *temporal density* or *temporal richness* of experience, another idea related to “subjective duration” that is important to our discussion. For example, we might picture Slowly as having more information packed into his experience every second than Quickly - perhaps by perceiving more fine grained temporal detail than Quickly - or as capable of having more conscious thoughts every second. Later I discuss how to relate subjective duration to temporal resolution and other notions of temporal richness. In particular one might try to substantiate the idea of a phenomenal metric by reducing it to a measure of temporal richness. I will explain later in the paper why I’m skeptical about this idea.

The kind of phenomenal metric that I’m interested in debunking here would be an *intrinsic* property of temporally extended portions of experience. Although I think there

is no such measure – or at least not one that plays the role that we would like phenomenal duration to play – I do think that there is an *extrinsic* property of extended experiences, whose existence contributes to our sense that there is also an *intrinsic* measure. This extrinsic property is a matter of how long an experience seems *retrospectively*. Just as external events have experienced durations, we have a sense of the length of our experiences themselves. For example, if I have been in pain for 5 minutes, then I have a retrospective sense of how long the pain been going on for. Note that 5 minutes of pain might seem longer for Slowly than for Quickly, even if we accept the notion that this is consistent with neither of them misperceiving the length of the pain. We might want a notion of retrospective apparent duration that captures this possibility: perhaps this is a matter of them perceiving different relational durational properties, or perhaps “apparent duration” in this sense is a primitive secondary quality, or a disposition to produce retrospective experiences with a certain duration phenomenology. I won’t adjudicate between these different views here. I will refer to this property – whatever it is – as *retrospective phenomenal duration*, to be contrasted with *intrinsic* phenomenal duration.

On the Retrospective view, the closest we can get to a property of “experienced duration” that belongs to extended experiences is this retrospective property; there is no intrinsic phenomenal duration. Although this is the view I will argue for, there are ways in which it is quite counterintuitive, which I want to be clear about before we proceed; this will also help motivate the discussion for those who are antecedently skeptical about the idea of an intrinsic phenomenal metric.

The intuitions that support the existence of an intrinsic phenomenal metric are best brought out by thinking about the role such a metric might play in practical deliberation. When making practical deliberations, we are sometimes concerned to *quantify* the amount of a certain kind of experience a scenario would involve. For example, consider choosing between an hour of constant pain at a certain intensity, and two hours of pain at a certain intensity. There are various considerations that could be relevant to you here – for example, you might choose the shorter pain, in part because it uses up a smaller proportion of your day, and you are a busy person. But surely the main reason why the one hour pain is preferable, is that it involves *less pain*.

What is the relevant sense in which there is *less* pain on that option? The naïve view to take is that there is less pain in the sense that the pain *objectively lasts less time*. More precisely, you might think that the correct way to evaluate the amount of pleasure or pain in a given temporally extended episode is to take a function representing the momentary intensity of the experience at each time, and integrate it over (objective) time. This intuitively powerful idea has been developed in the literature in psychology and economics on measuring utility. For example, Kahneman, Wakker and Sarin (1997) stress the importance of distinguishing between retrospective assessments of utility, prospective assessments of utility, and a measure of “experienced utility” which we get by integrating over time a function of momentary utility as measured at different times during an experience (for example, by asking subjects to rate the current intensity of an experience). The point of measuring “experienced utility” in this sense is that it is supposed to be normatively significant, providing a measure of how much utility an

episode *really* contained, as opposed to the utility we may, perhaps erroneously, assign to it retrospectively.

However, although the measure we get by integrating over objective time is *prima facie* a good measure of the quantity of pain, it is not, I believe, the measure most people would, on reflection, take to be normatively significant. I think the dimension of integration we really care about is not objective duration, but *subjective* duration (in some sense that will need clarifying; there are also complications here related to the fact that people are in some ways “duration insensitive” in rating experiences, although this doesn’t ultimately matter for the point I’m making here (see footnote)²). This can be seen with the following example. Suppose again that you are faced with a choice between two sessions of pain of equal constant intensity, except that this time each session objectively lasts the same amount of time - one hour, let’s say. Nonetheless, there is an important difference between the sessions. In one session, the rate of neural processing in your brain will be uniformly sped up by a factor of two just prior to the session. You know that this will mean that the hour of pain will be (in some sense) subjectively exactly like *two* hours of pain of the same intensity felt under normal circumstances. So, if the decision between the sessions is to be made based on how the sessions will feel subjectively, the situation is really exactly like a choice under normal circumstances between two hours and one hour of equally intense pain. Common sense says the reasonable choice to make in these circumstances would be to select the session in which the pain has a shorter subjective duration, despite having the same objective duration, and involve the same intensity of pain at each moment.³

² A well-known phenomenon in this area, first documented by Kahneman (et al.) (1993), is that subject’s retrospective judgment about how bad a pain is are well correlated with the intensity of its peak and ending, and quite poorly correlated with its duration. For example, subjects actually prefer a pain if it is extended with a period of less intense pain! However, these results don’t show that people’s reflective view of what matters in deciding between options, is not the amount of pain, as measured by integrating intensity over objective or subjective duration. As Kahneman himself has emphasized, the preferences people exhibit in these cases violate a basic temporal monotonicity principle guiding decision making (you can’t make an option better by adding something bad to the end of it), a principle most people presumably *would* accept on reflection. Ariely and Loewenstein (2000) point out that people quite reasonably do not treat duration as relevant when communicating to others the value of a past experience, even if they *do* take this into account in prospective decision making. Relatedly, in some prospective decision making tasks (as opposed to retrospective evaluation tasks), the value subjects attach to outcomes involving different painful experiences *has* been found to be linearly related to the duration of the experiences (Read and Loewenstein (1999)).

³ Notice that we would make the same verdict regardless of the relative objective lengths of the pains: even if one pain is considerably objectively longer than the other, if it has a shorter *subjective* duration, that is a reason to prefer it. If there is large discrepancy in the objective lengths of the pains, other factors relevant to the decision come into play: as I mentioned, the objectively longer pain may be more inconvenient because it takes up more of your time. The point here is that being subjectively shorter is one very important reason to prefer a pain, even if it has to be balanced against other considerations.

The idea of a phenomenal duration metric seems tailor made to make sense of these preferences. Intuitively, there is an intrinsic difference between these pains with different subjective durations that is an aspect of what it feels like to have the experience, has to do with the felt duration of the experience, and which allows us to quantify an amount of pain in each case. But despite the naturalness of this interpretation, I think is wrong, as I have said; in fact I think there is no straightforward way to quantify the amount of experience you have over time in a way does justice to our intuitions about this, because these intuitions assume that extended experiences have “felt duration” in an intrinsic sense. I think that extended experiences only have “felt duration” in the extrinsic sense described above. At the end of the paper I will discuss in more detail the ways in which this might require rejecting very plausible ideas concerning how to quantify pains and pleasures. Despite such revisionary consequences, I think that the arguments against the Phenomenal Metric view are strong enough to warrant rejecting it and accepting my alternative.

I now turn to presenting these arguments. I will advance several kinds of considerations against the Phenomenal Metric view. First, the Phenomenal Metric view predicts that duration illusions are “global” rather than “local”, in a sense I will explain, a prediction which may conflict with the existing empirical evidence on the topic. Second, the existence of phenomenal time conflicts with my preferred “atomistic” view of temporal perception and the temporal organization of experience, a view that I will contrast with “extensional” views, which are much more accommodating to a phenomenal metric. Thirdly, I will also argue that attempts to vindicate phenomenal time by reducing it to other measures of “experiential density” – for example, to various different ways of measuring the amount of *information* flowing through awareness per second, do not work.

3. Local and Global Duration Illusions

Note that on the Phenomenal Metric view, distortions in subjective duration are a global phenomenon, because there is a single subjective metric associated with the whole stream. So if a visual duration illusion occurs, the theory predicts a subjective stretching or warping across sense-modalities will occur, so that any simultaneous experiences in other parts of the conscious field will also be warped. However, it is not clear that this prediction is consistent with what we actually find. Parayidath and Eagleman (2007) explicitly discuss this prediction of the phenomenal duration model, and present evidence against it. For example, an auditory oddball does not cause a correlated subjective stretching in vision: in particular, it does not cause a simultaneous visual flicker to be perceived as having a lower frequency.

In general, we would only expect a global correlation of different duration percepts if there is a single timing mechanism in the brain that is responsible for all temporal processing associated with consciousness. But much evidence points to the alternative view that there are specialized timing mechanisms at different temporal scales and both

across and within modalities, suggesting that duration illusions need not global (see Mauk and Buanomano (2004) and Grondin (2010) for reviews).

The proponent of a phenomenal metric could respond by retreating to a view on which there isn't a single phenomenal metric, but different metrics associated with different modalities, or even with different aspects of a single modality. Rather than thinking of the stream of consciousness as like a single textured piece of rubber that can be stretched different amounts in different places, we revert to an image of it as a fabric of interwoven pieces of rubber that can be independently stretched. Such a view complicates the phenomenal picture, and raises embarrassing questions like: exactly how many independently stretchable sub-streams does consciousness have? Rather than pursuing such objections to this version of the Phenomenal Metric view, however, I will proceed by explaining another, perhaps more fundamental reason why the view is wrong: it is inconsistent with my preferred "Atomic" view of how experience is organized in time.

4. The Atomic View, the Extensional View and Phenomenal Duration

If experiences are organized by a phenomenal metric into "phenomenal time", then we could in principle extract a single narrative concerning how the world appears to be playing out in time by looking at the organization of your experiences in phenomenal time. However, I believe that the view that experiences are organized in this way is fundamentally mistaken. Instead, I adopt what I call the "Atomic" view of temporal experience.

Unfortunately, I will not be able to give a very full argument for the Atomic view, or a very detailed elucidation of what the view consists in – I do this elsewhere (Lee (manuscript), Lee (forthcoming). Grush (2005) also defends a version of the view). Here I will have to rely on a quick intuitive characterization of the view, and its main opposition, the so called "Extensional" view, which I think is implied by the existence of a phenomenal metric. The Atomic Theorist and the Extensional Theorist agree that we have experiences as of temporal phenomena like duration and temporal order (for dissent on this see Chuard (2011)), but disagree about how these experiences are themselves organized in time, and how it is that they present these temporal features. On the Atomic view, an experience of a temporally structured array of events, such as A happening before B, does not itself have any temporal structure at the experiential level; for example, it does not have as distinct temporal parts your experience of A, and your experience of B; these experiences *happen at the same time*, even though they present A and B *as* happening at different times. The temporal structure is in the *content* of the experience, not in the objective temporal structure of the experience itself:

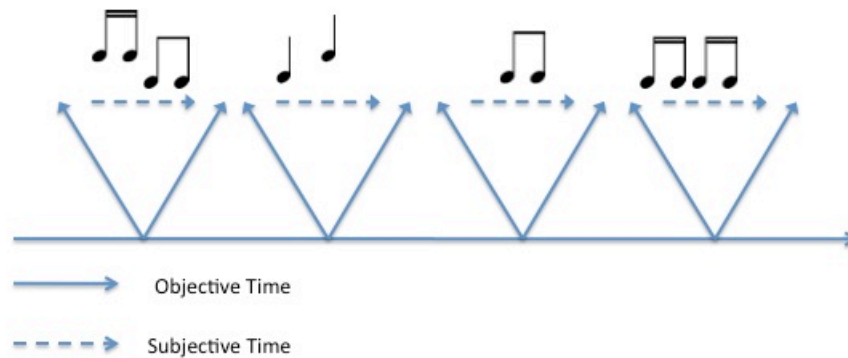


Fig. 2 – the Atomic View.

On this view, the stream of consciousness is a series of such atomic temporal windows. We can talk about the experience you had during, say, a five minute period of time, but this is really just a way of talking about the series of atomic experiences you had during this time. Each Atom might be associated with “subjective time” in the sense that it presents events as having a certain temporal appearance. But there is a separate “subjective time” associated with each atom, not a single dimension that structures experiences across time.

Two important clarifications of the view are necessary (see Lee (manuscript) for more detail). First, such Atomic experiences need not be instantaneous. In fact, my view is that all experiences are realized by temporally extended physical processes in the brain, and that this means that they are themselves extended in time. This is consistent with Atomic view, because an Atomic experience could be realized by a complex physical process, without having shorter *experiences* as proper temporal parts. In particular, the temporal stages of the realizing process might be too short lived to realize any experiences. Second, such temporally extended atoms might overlap in time (even if they don’t overlap by sharing temporal parts) forming a kind of messy continuum rather than a finite series of discrete bursts. So there is a distinction between an Atomic view, and a “discrete” view of experience.

The Atomic view contrasts with an Extensional View, on which temporal experiences are experiential processes, rather than experiential atoms. On this view, a temporal experience has proper experiential parts whose organization in time in some way reflects the temporal content of the experience (the view is developed and defended in detail in Dainton (2000, 2010)):

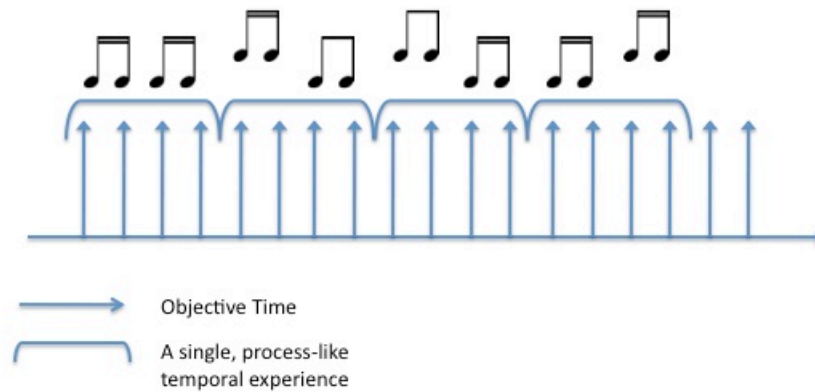


Fig. 3 : the Extensional view. This diagram depicts process-like temporal experiences as disjoint from one another, but the view is perfectly consistent with them overlapping by sharing temporal parts (as they do on Dainton’s (2000) “Overlap” model).

Elsewhere (Lee (manuscript)) I discuss in detail what exactly is involved in holding an Extensional View. In some ways the terminology here is unfortunate, because there a number of different claims that Extensional Theorists like Dainton typically want to make that are best kept separate. For our purposes, the important claims that are relevant are what I call the Process View and the Mirroring View (Phillips (2010)). On the Process View, temporal experiences are processes with experiences as proper temporal parts. On the stronger Mirroring View, there is a structural correspondence between the temporal parts of the process-experience and the temporal parts of the perceived scene. For example, if you perceive a number of sounds that form a melody, then your experience contains separate experiences of each sound as distinct temporal parts of the overall unified experience. Stronger forms of mirroring may obtain; in particular, the matching may be required to be order or duration preserving: for example, the *order of your experiences* of the sounds and the *experienced order* of the sounds may be required to be the same. Here I will not assume that these stronger forms of matching are part of the Extensional view, in fact I want to consider a development of the view on which the temporal parts of an Extensional experience are organized in both objective time *and* in phenomenal time, allowing for a dissociation between, e.g. the objective duration of an experience and the experience *of* duration that it involves (Fig. 4).

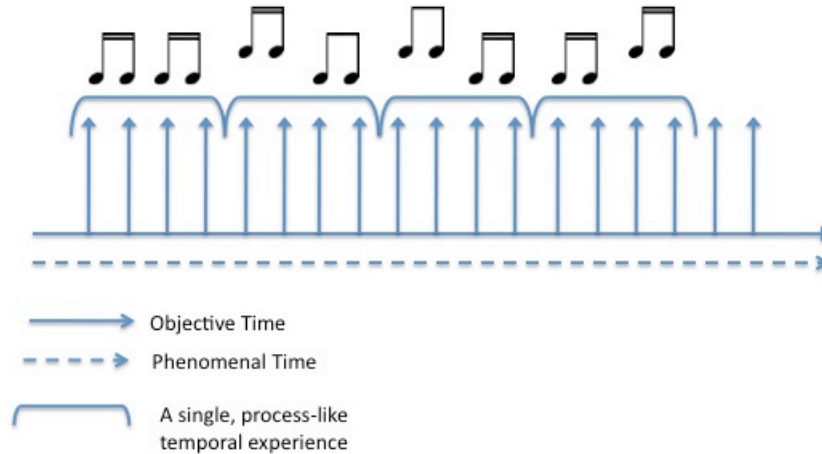


Fig. 4 – The Extensional View with a phenomenal duration metric.

Since phenomenal time provides a different measure on the stream from objective time, the experience of the melody can be warped and stretched phenomenally in various different ways, consistent with it having a particular objective temporal structure (we could even allow phenomenal order and objective order to come apart).

The important point here is that the idea of a phenomenal metric can easily be combined with an Extensional View in such a way that there is a direct correspondence between the phenomenal duration of an extended experience and the phenomenology *of* experiencing the duration of some external event. Experiences of different durations correspond to different segments of the stream with different phenomenal durations⁴.

The same is not true on the Atomic view. On this view, *duration phenomenology is not a property of extended portions of the stream, rather it is a property of individual atoms*. Indeed, it is really only the atoms that have any phenomenal properties at all – at best, extended portions of the stream have derivative phenomenal features that supervene on the phenomenal properties of the atoms, and so are only “experiences” in a derivative sense. Each atomic temporal window may present events with different durations, and each such duration experience will have a certain phenomenology associated with it, and it might even be correct to think that each of these windows has associated with it a dimension of “subjective time” in which the presented events are organized. But this “subjective time” is a feature of a single atom, *not* of an extended series of experiences; and we will associate a different subjective time with each atom (see fig. 2). For this

⁴ An important part of the Extensional view that I haven’t mentioned is that some segments of the stream may be too long to count as a single experience, and therefore to involve any experience of duration. We only have an “experience” in the relevant sense if all the parts of the experience are unified, and unity may only obtain over fairly short periods of time, corresponding to the maximum duration that can be presented in a single experience. This means that longer stretches of experience may only have phenomenal duration in an extended sense – but I do not think there is any difficulty in extending the notion in this way.

reason, the Atomic view suggests that there is no such thing as phenomenal duration, understood as a global phenomenal metric that gives extended portions of experience an intrinsic felt duration; only atoms have intrinsic felt duration.

The fact that on the atomic view temporal phenomenology is a feature of individual atoms is reflected in the fact that the atomic view (but not the extensional view) allows for a kind of Dennettian “redrafting” in experience from one moment to the next (see Dennett and Kinsbourne (1997), Grush (2005)). Rather than there being a single narrative about perceived events that can be extracted from your experiences over time, it is possible that two events are presented as having one temporal relationship one moment, and then a moment later you are presented with a different relationship as the brain revises its estimate of what happened. On the atomic view, unlike on the Phenomenal Metric view, there may be no definitive way in which perceived events are organized in “subjective time”.

The Atomic view is not inconsistent with the idea that there is a systematic difference between Quickly and Slowly. For the Atomist, it can be conceived of as a difference in the phenomenal character of the atomic experiences they are disposed to have under different circumstances. For example, if they both perceive a 500 msc tone, they may both have an atomic experience (or more likely a series of experiences) that presents the tone, but it’s duration will have a different phenomenal appearance for each of them. In this sense, we can say that time passes at a different rate for them, although their rate of passage is not to be understood in terms of a phenomenal metric; it is a disposition to have certain kinds of atomic experiences caused by certain kinds of temporal phenomena. Note that one kind of atomic experience that will be particularly salient here is a retrospective experience of how long an experience (such as the pain experiences discussed above) has been going on for. The Atomic view is consistent with these retrospective experiences having a systematically different phenomenology for Quickly and Slowly, and so their extended experiences having different “felt duration” at least in an extrinsic sense.

Why, in brief, do I prefer the Atomic view? There are a number of considerations that tell in its favor, which I describe in detail in Lee (manuscript) and Lee (forthcoming). In my opinion, the most fundamental reason for preferring Atomism concerns how time is represented in the brain – I call this the “Trace Integration Argument”. Theorists proposing computational models of how different kinds of temporal information are extracted from a stimulus assume that we start with an input (like a pattern of retinal stimulation) in which “time is coded by time” in some sense, and the task of the computational process is to compare or integrate the different temporal stages of the input, recoding the temporal information into a form where it is explicitly represented *all at once*. I would claim that temporal experiences are realized by the output of such a process of trace integration, and are therefore realized by representations that code *all at once* how the world is changing over time. This in turn is a reason for saying that they have an Atomic, not a process-like structure.

There is much more to be said about this argument, and I try to spell it out in other work (Lee (manuscript)). Here I will assume that Atomism is the correct view of the temporal

organization of experience, and try to further develop a view of subjective duration that is consistent with it.

I argued that the Atomic view rules out the Phenomenal Metric view. A fan of a phenomenal duration metric may respond by trying to find ways to reconcile the views. In particular, the following idea might seem promising: we might try to find a measure of the *density in time* of experiential atoms, and hold that this can be integrated over time to get a measure on the stream that fits the job description of phenomenal duration – a derivative property that would supervene on the properties of the atoms. Given the point already made that duration phenomenology is a property of atoms and not of extended portions of the stream, it is already dubious whether any such measure could satisfy the phenomenal duration job description. However, despite this point, it is illuminating to consider the idea in some detail, which brings us to the next section.

5. Phenomenal Duration and Experiential Density

As mentioned above, when we reflect on the idea of slow-motion or high-speed experiences, one salient aspect of them is that they seem to involve either more or less temporal detail in a subject's experience per objective unity of time than in a normal experience. This leads naturally to the idea that subjective duration is in some way constitutively tied to temporal richness or density of conscious experience. It is not implausible that this could provide the elusive phenomenal measure we are interested in: it clearly has to do with what experience is like subjectively and 'how much' experience we have in a certain sense. Furthermore, there seems to be no reason why an Atomist could not acknowledge some such measure on experience. So perhaps the proponent of the Phenomenal Metric view can explain how their view is after all consistent with Atomism by proposing that phenomenal duration can be reduced to some such density measure.

An example in the literature where some such connection between information density and phenomenal duration is made is in Stetson et al. (2007). They tried to experimentally test the hypothesis that extreme stress can change the subjective rate of time's passage, as if often anecdotally reported. They reasoned that if time really does slow down under such circumstances then this would allow subjects to perceive the world with a higher temporal resolution than normal. To test whether stress improves temporal resolution, they tested for an improvement in visual temporal resolution in subjects entering free fall by throwing themselves off a raised platform (while falling, the subjects viewed a display rapidly alternating at a rate marginally too fast to discern in a normal resting state). It was found that this stressful situation did *not* improve temporal resolution, although subjects did retrospectively judge that their own jump lasted much longer than they would judge someone else's jump to have taken. Stetson et al. conclude that there is no occurrent change in a subject's experience during the fall, merely a retrospective sense that experience was longer than it really was - a view not unlike my retrospective view (although there are important differences).

Stetson et al. assume that if there were an occurrent change in a subject's experience of time passing during the fall, this would be at least partly constituted by a change in perceptual temporal resolution – a measure of the informational richness of experience.

One could object that there might not be such a tight connection between subjective rate of temporal passage and temporal resolution – an objection that I would be sympathetic with. I'll return to this momentarily – for now, we can think of Stetson et al.'s discussion as an illustration of the tendency to link phenomenal duration and experiential density.

How to measure information flow is a puzzling issue – is there an objective number of bits per second entering into your conscious mind? There are at least the following 4 distinct measures of “information” that might be relevant here:

- (1) The prior probability of the scenario presented to you by the experience (this is the “amount of information” in Shannon’s sense, usually represented as “bits” on a logarithmic scale).
- (2) The size of the representation underlying your experience, as given, for example, the number of binary yes/no questions that have to be answered to ascertain what you are perceiving, or the number of mental symbols used to represent a perceived scene.
- (3) Spatial or temporal resolution (as in Stetson et al.): roughly, a measure of how fine-grained in time or space the discriminations of a perceptual system are.
- (4) The number or arrangement of events used as “temporal cues” present in your experience.

The notion of a “temporal cue” deserves some explanation: roughly, the idea is that systems involved in time perception have priors for how many salient perceptual “events” happen per second, or how processes of familiar kinds tend to play out in time (think, for example, of speech perception). Duration is then gauged by applying these priors to information about the arrangement in time of the cue events (Tse (2004), for example, suggests that attention could expand the subjective duration of time by causing more temporal cues to be detected).

I should also note that I am not claiming that all of these four measures are actually well-defined for experiences of different kinds, merely that they are the notions that we might naturally look at in this area.

Rather than discussing these notions individually, I want to make a general point about their potential role in explaining temporal experience. It is crucial to realize that there are two very different ways of connecting information flow (in any of these senses) with duration phenomenology. We need to distinguish a *constitutive* and a *causal* sense in which information flow can be linked with temporal experience or temporal perception.

On the constitutive view, phenomenal duration just *is* the amount of information presented in experience during a certain period (or a function of “experiential density” in some non-informational sense). The idea is to *reduce* phenomenal duration to something else (I believe that Eagleman and Pariyadath’s recent (2009) suggestion that subjective duration just *is* “energy consumed” by certain perceptual processes, is a view in this category; Eagleman & Pariyadath intend energy consumed to be an index of information flow).

On the causal view, rate of information flow plays a *causal role* in the tracking of time's passage. The idea would be that the rate of information flow is a quantity that is used as part of a time-keeping mechanism: rather than having dedicated oscillations or temporal regularities set up to allow the measurement of duration, the brain exploits the fact that processes not primarily dedicated to tracking time have their own invariant temporal features that can in principle be used to measure duration. (One could think of this as a version of the temporal cue idea, where the brain is implicitly using priors about the temporal relationships between events of certain kinds to track time, where now the relevant events are *neural* events rather than external perceived events). On this view the experience of duration is not *constituted* by anything related to informational density, rather the mechanism that allows the tracking of time happens, as contingent matter of fact, to use informational density as a temporal cue. (See Ivry and Schlerf (2008) for a review of dedicated vs intrinsic timing mechanisms).

A serious problem with attempts to reduce phenomenal duration to informational richness (in any sense), it seems to me, is that the link between the two is far more plausible when understood in the weaker causal sense than in the constitutive sense. There are a number of salient points here. Recall that phenomenal duration is a measure of the quantity of experience that one has that is somehow supposed to reflect a feeling of how *long* an experience lasts: thus it is constitutively linked to *duration perception*. However, presumably your experiences could have a certain level of informational density even if mechanisms involved in tracking time were completely disabled⁵. Informational density only results in duration perception if it is hooked up to a larger clock mechanism that is explicitly registering this information flow and using it as a measure of time. Suppose we had a creature whose experiences involve flow of information, but who is not equipped with such internal clocks. Would their experiences have phenomenal duration? If so, then we have to give up on the claim that phenomenal duration is constitutively linked to the perception *of* duration, which seems implausible.

In response to this, one might claim that information density is a necessary *component* of phenomenal duration, which must also play a certain functional role in tracking time to be involved in temporal phenomenology. So it *is* constitutively linked to temporal perceptual experience, even if it can occur in a being that has no such experience. But against this, surely temporal perception is at best only contingently underwritten by mechanisms that track the rate of information flow: surely there could be a conscious being whose perception of duration was instead underwritten exclusively by time-dedicated circuits that do not exploit information flow. So information flow is neither necessary nor sufficient for temporal experience.

There is a connection between these points, and the Trace Integration argument for the Atomic view I briefly outlined in the last section. If information flow did play a causal role in tracking duration, this would presumably be through the operation of an accumulator mechanism that measured how much information is processed between an

⁵ This point is not correct if temporal richness is understood as temporal resolution, which requires temporal perception – but the suggestion that rate of passage is constituted by temporal resolution is problematic for other reasons I give.

onset and offset point, and therefore indirectly, how much time has passed. An explicit representation of duration would be realized by the *output* of the accumulator, which would therefore be a better candidate for what underwrites a duration experience, than the extended information flow between onset and offset. If a duration experience is underwritten by this simultaneously integrated accumulator output, it is presumably an atomic experience of duration, not an extensional experience. Further, this atomic experience of duration would be only *causally* related to the amount of information contained in your experiences between onset and offset; but to *be* phenomenal duration, a measure on experience needs to be *constitutively* linked to the experience of duration.

There are less general considerations that also tell against identifying information flow with phenomenal duration. One important point is that most of the measures of information flow I can think of are likely to give different measures of information flow for experiences in different modalities, or in one modality in different circumstances, despite the fact that we would not suppose time to be flowing at different rates in each case. Consider the fact that hearing has much higher temporal resolution than vision: despite this fact, time does not seem to pass more slowly in hearing than in vision. Similarly, it does not appear that a sudden reduction in spatial or temporal resolution in a certain modality (e.g. of the kind that would occur if I took my glasses off) immediately causes time to appear to speed up (compare how taking your glasses off doesn't suddenly make everything look smaller, despite a reduction in spatial resolution). Similarly, if I simply close my eyes, thus massively reducing the amount of information flowing through consciousness, this doesn't make time speed up. Finally, many of these measures of information flow are only applicable to perceptual experience in particular; but intuitively there could be subjective duration in a purely non-perceptual form of consciousness – for example, in a form of consciousness that involved only mental images, thoughts, and sensations like pains. Perhaps we can find a notion of Experiential Density that applies in these non-perceptual cases, but I suspect that the same general point will apply : that the relevant kind of density is at most contingently associated with temporal experience as part of a time-keeping mechanism.

It is true that certain kinds of information flow have been argued to be correlated with subjective duration, on the basis of experimental evidence. For example, as I already mentioned, Tse (et al) (2004) suggest that the Oddball effect is caused by increased attention to the Oddball stimulus, resulting in more temporal cues for duration being detected than normal. And Eagleman and Pariyadath (2009) suggest that the effect is explained by a shortening of subjective duration in the stimuli immediately preceding the oddball, due to an increase in coding efficiency known as “repetition suppression”. The idea is that is that subjective duration is correlated with how hard the system has to work to process information about a stimulus, and that repetition increases efficiency. The point I would make is that both these hypotheses are more plausibly interpreted in the causal rather than constitutive way (although admittedly, Eagleman & Pariyadath do seem to intend a constitutive reading). Unless temporal cues or energy expended are wired up to play a causal role in keeping track of time, they will not be involved in explaining the subjective sense of how long an experience lasts.

The point here is not that information flow is not an interesting way to measure how much experience you have, but rather that it is not a measure that is constitutively linked to temporal perception in the right way to constitute phenomenal duration. It is reasonable to want your experiences to convey as much information about the world as possible, both as a means to other goals, and as an end in itself: one might think that richer experiences are intrinsically preferable to more impoverished ones. But it would be a mistake to think that such measures are more than indirectly related to our sense of how fast time is passing, or “how much” – in a subjective temporal sense - of a certain kind of experience we have had (such as a pain).

To sum up, attempts to save phenomenal duration by reducing it to a measure of experiential density in terms of information flow do not work. This does not definitively show that the experiential density idea does not work, because there might be other ways of measuring it other than in terms of perceptual information flow⁶. But I suspect a similar point would apply to any suggested measure – it only has a connection with duration phenomenology if there is a cognitive clock using this measure to keep track of time; but then the relevant density measure is only causally, not constitutively linked with the experience of duration.

This is the final part of my case against the existence of a phenomenal duration metric. In short, I have argued that the Atomic view is inconsistent with experiences being organized in “Phenomenal Time”, and that attempts to reconstruct the idea of a phenomenal metric in terms of the temporal richness of experience do not work. In the last section, I consider an important problem that my positive view generates.

6. Is Subjective Duration Response-Dependent? The Paradox of Subjective Time.

I have argued against the existence of a phenomenal duration metric – but how are we to understand the difference between subjects like Quickly and Slowly if not in terms of phenomenal duration? As I said, I think the most important difference between them is that they are disposed to have phenomenally different experiences of the same durations and rates of change. There is an important question about what these atomic phenomenal differences consist in, but rather than pursue it here (it is a complex question that requires a long discussion in its own right), I want to look in this last section in more detail at the possibly revisionary consequences of holding this view. In particular, as we saw above, the *quantity* of pain, pleasure, or other kinds of experience a situation involves seems a relevant factor in deciding whether it is better or worse than other situations. A phenomenal metric helps to make sense of this idea. Furthermore, as I will now argue, if there is no such metric, this makes it difficult to quantify experiences in a way that makes sense of our *prima facie* normative views about the values of different experiences.

⁶ For example, Phillips (2012) suggests that subjective duration is in some way linked to the amount of non-perceptual conscious “mental activity” that a subject enjoys during a period of time. My point would be that this is only viable if there exists a timing mechanism that measures conscious mental activity as a way of measuring time – conscious mental activity does not on its own entail any experience of duration.

To see this, let's go back to thinking about the case of the two pains that I mentioned in section 1. We noted that, intuitively, even if two pains have the same constant intensity and last the same amount of time, there can still be reason to prefer one over the other, if one of them has a shorter subjective duration. For example, if both pain A and pain B last an hour, but pain B is subjectively just like a 5 minute pain, you should go with pain B.

In what sense might there be an experiential difference between pain A and pain B? When we address this question from the perspective of the Atomic Theorist, we are led to the rather paradoxical conclusion that there may after all be *no* relevant intrinsic phenomenal difference between them! For example, if Quickly and Slowly both experience 5 minutes of equally intense pain, arguably there is no relevant difference between their extended experiences, even though time is passing much faster for Quickly than for Slowly. How so? Well, at each moment their experience is characterized by their feeling pain at the same intensity. Because Atomism is true, their experience over time supervenes on their experience at each individual moment. Moreover, the pains last the same amount of objective time, so there is a simple phenomenology-preserving mapping between their pains at each instant. In this sense, paradoxically, the pains are exactly the same in relevant respects (see fig. 5).

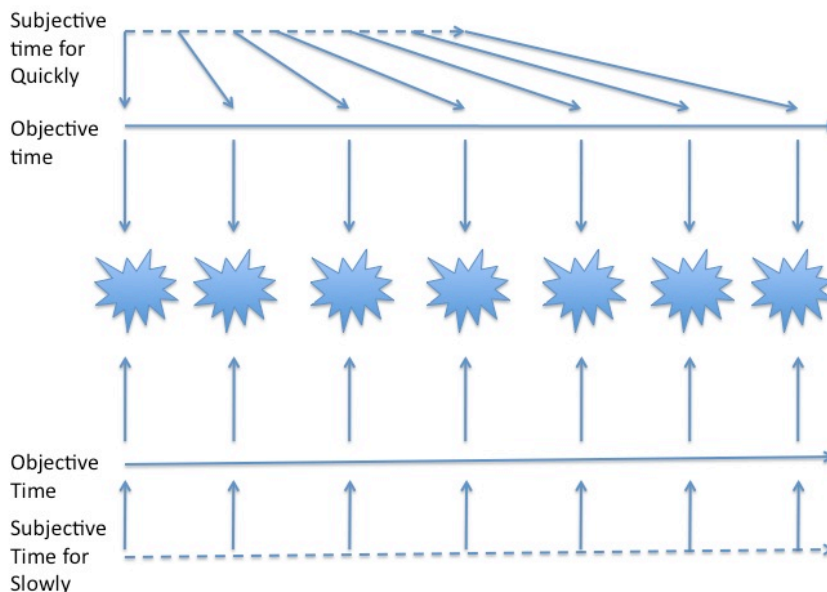


Figure 5. The “Paradox” of Subjective Duration

If the Phenomenal Metric View was correct, this would not be the right conclusion. Even if the pains were the same at each moment, there would remain the fact that they have different phenomenal durations – a further phenomenal feature of *extended* portions of pain, which does not supervene on their moment-by-moment phenomenal character. But on the Atomic view there is *only* the moment-by-moment phenomenal character. This is what creates the paradoxical conclusion.

To be clear, it is only the pains themselves that are being said to match each other in this way. During the 5 minute period, Slowly may be capable of having more thoughts than Quickly; and if at any point each reflects on how long it's been since the pain started, it may seem to Slowly that more time has passed. The point is that relations to mental states such as these are all *extrinsic* properties of the pains, whereas intuitively there is a relevant *intrinsic* difference between them. It is this that the Atomist can arguably not accommodate.

I will say more about this shortly. First, note that the “matching phenomenology” point generalizes to portions of experience of a single normal subject. If (as I have argued) the objective duration of an experience is not a phenomenally relevant feature of it, there is a sense in which 5 minutes of pain felt at a constant intensity by a normal subject is qualitatively identical to 15 minutes of pain felt at the same intensity by the same subject. There is a phenomenology preserving mapping from the momentary states of the 5 minute experience at time t after onset, to the stages of the 15 minute experience at time $3t$ after onset. So, given that the difference in objective duration is not phenomenally relevant, there is no intrinsic experiential difference between these extended pains.

Is this a sufficiently strange conclusion that we should reject one of the assumptions that lead to it, such as the Atomic view, or our rejection of phenomenal duration?

It might be suggested that the problem is generated by an assumption that there are only instantaneous experiences. What if the Atomist instead claimed that each atom is temporally extended (as I suggested above that they should)? I don't think this makes any difference. Imagine, for example, taking pain A and pain B and replacing each instantaneous slice with an extended atom that has the same phenomenal character, but which lasts 1 ms and is centered on the same time as the instantaneous slice was. We get something like a “continuous” series of temporally overlapping atoms, rather than a continuous series of slices. But it is hard to see how merely changing the objective duration of each slice in this way could make any difference to the problem we are dealing with: we will still have the relevant phenomenology preserving mappings.

Another natural suggestion is that pain A and pain B differ in that at each moment there is a *phenomenology of time passing at a certain rate*, a rate that is faster for Quickly than it is for Slowly. One could develop this in terms of experiential richness or information flow, an idea already dealt with above. A further problem for this idea, perhaps more important in the present context, is that if there is such a thing as a *rate* or *density* of experience flowing through time, *it is not a phenomenal property*, and therefore not a phenomenal property of atomic pain experiences that could be integrated over time to get a phenomenal metric. What I mean is that two subjects can have moment-by-moment qualitatively identical experiences, despite enjoying different subjective rates of experiential flow. For example, suppose Slowly watches a 2 hour movie, and Quickly watches an accelerated version of the movie that lasts only 1 hour. Quickly's and Slowly's experiences might be qualitatively identical in the sense that Q's experiences at t minutes into the movie might be subjectively just like Slowly's experiences at $2t$ minutes into the movie, despite the fact that they are experiencing time passing at different rates. That phenomenal rate of passage is not a phenomenal property is actually something that drops out of the Phenomenal Metric View – on that view “rate of flow” is

a function of both phenomenal time – a phenomenal property – *and* objective time – not a phenomenal property. It is the number of units of phenomenal time that pass *per* unit of objective time. But even if we reject phenomenal duration as a basic phenomenal property, the point remains good.

Given the failure of these responses to the problem, the only way to resist the “paradoxical” conclusion, I would suggest, is to reject Atomism and embrace the view that the phenomenology of experience over time does not supervene on the character of momentary states, because there is a phenomenal metric that applies to extended portions of the stream. I personally think the case for Atomism is compelling, so I prefer to embrace the seemingly paradoxical conclusion. We need to be candid, however, about why taking the felt duration of an extended experience to be extrinsic is revisionary of common sense. Consider the following three points:

First of all, it doesn’t appear that changing the character of one’s retrospective impression is a way to change how bad a session of pain is, because it is not a way of changing the intrinsic features of the pain. For example, being told that *after* a session of pain, before you have time to reflect back on the pain, someone will intervene to make it seem like the pain was very short, hardly serves to make the pain any more preferable. The situation is perhaps illuminatingly compared with the case of the *existence* of pain, rather than the amount of pain you suffer. Certain anaesthetics are said to operate not by preventing pain as it is inflicted, but by preventing the subject of the pain from remembering it afterwards. What is disturbing about this, of course, is that a pain still exists regardless of whether or not you remember it. Furthermore, it seems wrong to say that a pain not remembered is a pain not worth caring about – a lack of memory may mitigate bad effects like painful memories, but it doesn’t render the pain completely “harmless”, so to speak. The Retrospective theorist appears to be taking a view that is implausibly similar to a view on which the existence or negative utility of pain depends on the existence of later memories.

Second, how long a pain seems to last retrospectively might depend on *when* we reflect back on the pain. During the moments after the pain, our retrospective impression of it might even change quite dramatically. So it seems as if there isn’t such a thing as *the* retrospective duration of a pain, but rather many such retrospective durations. But isn’t there some way of quantifying the amount of pain that isn’t variable in this way? Related to this is the fact that I might simply have no retrospective impression of the length of the pain at all. Perhaps the intensity of the pain was completely disorienting, so that I have no sense of how long it went on for. Does that mean that there’s no sense at all in which the pain had a quantifiable “subjective duration”?

Third, if Quickly and Slowly have different retrospective impressions of the duration of their pains, and these retrospective impressions are both veridical impressions *of* some feature of the pains (and so not straightforwardly just impressions of objective duration), we can ask : what feature is this? It would appear that the pains must have some distinguishing feature other than their relation to different retrospective impressions, otherwise there will be nothing for these retrospective impressions to be *about*. A proponent of a phenomenal duration metric might claim that surely the most plausible candidate for such a remembered feature would be phenomenal duration itself. But what

should the Retrospectivist say that a retrospective impression of duration is an impression of?

On this third point, the Retrospective Theorist does have a reasonable reply. They can say that retrospective impressions of the duration of experiences are just one case of duration impressions in general, which are not typically directed at experiences but rather at external events. When Quickly has a an impression of the duration of some physical event in the environment which is different from the impression that Slowly has, we can also ask what feature of the event Quickly is perceiving, and again it seems that it is not simply the objective duration of the event. But we cannot say that this physical event has phenomenal duration, because it isn't an experience. In so far as we think that the phenomenology of Quickly's experience has to be explained as a relation to some property of the event, I think the property will have to be a relation between the objective duration of the event and some feature of Quickly himself, such as the rate of neural processes in his head that are used to track time. As I suggested above, saying what more specifically this relational property might be is an interesting and tricky issue which I will not pursue here. The point is that whatever it is, it may be the kind of property that experiences themselves can have, and which we can say is what is represented in retrospective impressions of duration.

On the first and second points, I see no option but to just accept these consequences. I used to think that these points were sufficiently costly to warrant rejecting the Retrospective View, but now I don't think this. Importantly, I think that the retrospective theorist can say that there is nothing that we can introspect that directly contradicts their view. In so far as we think that there is an intrinsic difference between 5 minutes of pain and an hour of pain, this is a theoretical assumption that we might very naturally make, but not one that is required to explain the introspective data. Given that the Retrospective view fits the empirical facts better (as I have tried to argue), we should believe it even though it conflicts with these deeply embedded ideas.

If the subjective duration of experiences is response-dependent in this way, how does that affect the rationale for different preferences about "quantities" of experiences like pain? One possible view is revisionary. It might be pointed out that these preferences assume that there is an intrinsic difference between the experiences we are choosing between; furthermore, a retrospective impression that a pain lasted a long time is not enough on its own to make it worse than some other pain that is not linked to a similar impression. It is not the retrospective feeling that we dread, that makes the pain terrible, but the pain itself. It can seem as if the truth about subjective duration leaves these preferences peculiarly ungrounded, and thus arguably they should be revised.

This conclusion would of course be disturbing to Hedonists, who think that the value of a certain scenario should be calculated by quantifying the amount of pleasure and pain it involves. If there is no straightforward way to quantify experiences in a way that is relevant to our preferences, the theory is ill-defined. But it is not just Hedonists who should be concerned; almost all theories of what matters include quantities of pleasure and pain as at least one factor to take into account in calculating the value of a possible outcome. If pain and pleasure can't be intrinsically quantified, we will have to rethink this idea. Clearly then, this is a matter of significance to debates about what matters,

which in turn has significance for normative debates in economics and other areas concerned with measuring people's welfare; as such it deserves further discussion, which I hope to pursue elsewhere.

6. Conclusion

I have argued that although there are intuitive reasons for believing that experiences exist in a dimension of "phenomenal time" that measure how fast experience flows by each second, there is in fact no such thing as phenomenal time. The stream of consciousness is a series of atomic states that represent temporal structure without themselves having significant temporal structure. Duration phenomenology is a feature of these atomic states, not of extended portions of the stream of consciousness that can be divided up into experiential stages with different phenomenal durations. Moreover, I argued that attempts to reduce phenomenal duration to measures of information flow in perception fail because the quantities are at best contingently rather than constitutively related. The resulting view is that extended experiences only have subjective duration in a thin response-dependent sense. This conflicts with certain ideas we naturally have about the temporal character of experiences, and threatens to undermine the rationale we give for certain preferences between experiences. I argued that these costs are not sufficiently great to warrant believing in phenomenal duration.

References

- Ariely, D., & Loewenstein, G. (2000). When does duration matter in judgment and decision making? *Journal of Experimental Psychology General*, 129(4), 508-523.
- Chuard, P. (2011). Temporal Experiences and Their Parts. *Philosopher's Imprint*, vol.11 no 11.
- Dainton (2000) - Stream of consciousness: Unity and Continuity in Conscious Experience, Routledge.
- Dainton, B. (2010) – Temporal Consciousness. Stanford Online Encyclopedia of Philosophy entry.
- Dennett, D. C., & Kinsbourne, M. (1997). Time and the observer: The where and when of consciousness in the brain. *The nature of consciousness: Philosophical Debates*, 141-174.
- Eagleman, D. M. (2008). Human time perception and its illusions. *Current opinion in neurobiology*, 18(2), 131.
- Eagleman, D.M. and Pariyadath, V. (2009). Is subjective duration a signature of coding efficiency? *Philosophical Transactions of the Royal Society*. 364(1525):1841-51.

- Grondin S. (2010) Timing and time perception: A review of recent behavioral and neuroscience findings and theoretical directions *Attention, Perception, and Psychophysics*, 72 (3) , pp. 561-582.
- Grush, R. (2005). Internal models and the construction of time: Generalizing from state estimation to trajectory estimation to address temporal features of perception, including temporal illusions. *Journal of Neural Engineering*, 2(3), S209.
- Ivry and Scherlf (2008). Dedicated and Intrinsic Models of Timing. Trends in Cognitive Science. Volume 12, Issue 7, July 2008, Pages 273–280.
- Kahneman, D., Frederickson, B. L., Schreiber, C. A., and Redelmeier, D. A. 'When more pain is preferred to less: adding a better end', *Psychological Science*, 4 (1993).
- Kahneman, D., Wakker, P. P., & Sarin, R. (1997). Back to Bentham? Explorations of experienced utility. *The Quarterly Journal of Economics*, 112(2), 375-406.
- Lee, G. (forthcoming). Atomism, Extensionalism, and the Continuity of Experience. In Oaklander (ed.) (forthcoming) *Debates in the Philosophy of Time* (Bloomsbury).
- Lee, G. (Manuscript) – Temporal Experience and the Temporal Structure of Experience.
- Mauk and Buanomano (2004) – The Neural Basis of Temporal Processing. Annual Review of Neuroscience. 2004. 27:307–40
- Pariyadath, V. and Eagleman, D.M. (2007). The effect of predictability on subjective duration. *PLoS One*. 2(11) : e1264.
- Phillips, I. (2010). Perceiving temporal properties. *European Journal of Philosophy*, 18(2), 176-202.
- Phillips, I. (2012). Attention to the passage of time. *Philosophical Perspectives* 26(1), 2012.
- Read, D. and Loewenstein, G. (1999). Enduring pain for money: decisions based on the perception and memory of pain. *Journal of Behavioral Decision Making* 12(1), 1–17.
- Stetson C, Fiesta MP, Eagleman DM (2007). Does time really slow down during a frightening event? *PLoS One*. 2(12) : e1295.
- Tse, P. U., Rivest, J., Intriligator, J. and Cavanagh, P. (2004). Attention and the subjective expansion of time. *Perception & Psychophysics*, 66(7), 1171-1189.

