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A Quantum Theory of Felt Duration

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A Quantum Theory of Felt Duration

Carla Merino-Rajme

A DISSERTATION
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Abstract

How do we experience time? When you experience today's walk as taking twice as long as yesterday's and then judge that this is so, what is going on? What is it to experience a walk *as taking twice as long as* another? Do I look at some mental analogue of a watch, one available to me even when I am not wearing a watch on my wrist? Of course not. Nor is there a blinking red light in my visual field that measures how long events take. So do we really experience the durations of events, as opposed to just finding ourselves with judgments concerning their durations?

In this dissertation, I defend the idea that we experience durations—that there is something that it is like to experience an event as lasting for a particular amount of time. I develop a theory aimed at explaining what *felt duration* is, what is distinctive about it, and just how we experience events as having durations of different and yet comparable amounts.

It is crucial to this theory that there is a particular duration such that experiencing an event as having that duration has a distinctive phenomenal quality. This is the duration characteristic of what I call *a quantum*: the longest-lived temporal slice of a situation experienced as a 'tightly unified' whole. While a quantum provides the basis for our subjective system for measuring duration, it also marks a natural division between two distinct ways of experiencing duration: one for long-lived and another for short-lived events. The theory proves fruitful, offering different explanations for various illusions that, as I explain, ought to be distinguished.

What is it like to experience the duration of an event? For a long-lived event, it is the impression formed of how many quanta are involved in experiencing the event. For a short-lived

ABSTRACT

event, it is how much of its quantum's duration the event strikes us as taking up. Because a quantum is the unit of felt duration for both short- and long-lived events, their felt durations are comparable, allowing for a unified system for measuring felt duration.

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Chapter 1:

A Quantum Theory of Felt Duration

for Long-Lived Events

1.1 The Phenomenon: Felt Duration

Consider the following.

THE DANCE SHOW

It's a few minutes before 8 pm and you are running late for tonight's dance show. On your way into the theater, you see your friend Peter just coming out. As you both exchange a few remarks, you ask him how long the show lasted. He says: "I left my watch at home, but it *felt* like it went on for about an hour and a half."

Like Peter, we usually experience events as having particular durations. The experienced duration of an event can come apart from the actual temporal length of the event. That is, there can be illusions of felt duration, as the following cases illustrate.

THE SURPRISE PARTY

Your friends organized a fun surprise party for you. Two hours into the party you look at the watch with astonishment: you can't believe it's that late! *It feels like the party has just started.*

THE BORING MOVIE

You entered the theater expecting a comedy. The movie turned out to be a flat, silly story, with not much going for it. It's the fourth time you check your watch: you can't

believe time is passing so slowly! *What you've experienced as an hour has not really been more than 25 minutes.*

The coherence of these and similar cases suggests that there is something that it is like to experience an event as lasting for a particular amount of time. Otherwise it would not make sense to be surprised when you learn that the party or the movie was, respectively, a lot longer or shorter than it *felt*. This subjective sense of duration is captured in everyday expressions like “Time flies when you’re having fun” and “A watched pot never boils”. In using these expressions, we give voice to the idea that a certain event is *experienced* as taking either a much shorter or longer amount of time than it in fact takes.

My aim in this dissertation is to offer a novel theory of the experience of duration that accounts for the following intuitive claim.

EXPERIENCE OF DURATION Usually, we experience ordinary events as having durations, and these experiences provide the basis for our immediate judgments about the durations of those events.

EXPERIENCE OF DURATION will thus be the datum to be explained.

To appreciate what is at issue, consider denying EXPERIENCE OF DURATION by claiming that we do not really experience ordinary events as having durations. This would be tantamount to claiming that, with respect to the durations of events we go through every day such as meetings, walks, or telephone conversations, we are zombie-like. That is, there would be nothing that is what it is like to experience their durations. I find this very hard to believe. Indeed, the opposite seems to be the case: it is very unusual to go through these events without *experiencing* them as having some duration or other.

Contrast experiencing the dance show as lasting for about an hour and a half with, upon waking up, *guessing* the duration of your nap by saying the amount of time that first pops into your mind. Or contrast this experience with *estimating* the duration of your nap by looking at the positions of the Sun before and after you sleep. In the former case, you simply find yourself making the judgment; in the latter, you make it on the basis of an inference. In neither case is the judgment based on your *experience* of the nap as having certain duration.

Throughout the discussion, it will thus be important to keep in mind that EXPERIENCE OF DURATION is not *just* a claim about duration judgments. Instead, it is the claim that we usually *experience* events as having durations and that we form corresponding judgments on the basis of these experiences. In other words, it is usually *because* we experience the event as having a certain duration that we form a judgment about its duration.

The theory I aim at providing is thus not a theory that merely accounts for duration judgments. Instead, it serves to explain what the experience that gives rise to these immediate judgments is. More precisely, this theory serves to explain what *felt* duration is, what is distinctive about it, and just how we experience events as having durations of different and yet comparable amounts. The theory can also be used to explain how in certain temporal illusions felt duration can radically diverge from objective duration.

In this first chapter, I will offer a theory of felt duration for long-lived events such as parties, dance shows, and movie screenings. In the next chapter, I will extend this theory to account for the felt duration of short-lived events such as a glass falling off a table, a kid stepping into a puddle, and a bug flying across your laptop screen.

I begin section 1.2 by presenting a phenomenological puzzle that arises from considering cases like THE SURPRISE PARTY and THE BORING MOVIE. My positive account begins in section 1.3. There I develop a theory of the experience of duration of long-lived events according to which there is a specific duration such that experiencing an event as having that duration typically exhibits a particular phenomenal quality, a particular feeling. This is the duration characteristic of what I call *a quantum*. After characterizing these quanta and introducing a hypothesis about their objective durations, I develop a model according to which our experience of the duration of a long-lived event such as a party, a movie, or a dance show is the impression formed of how many quanta are involved in experiencing the event. I then put these ideas to work by explaining how the theory provides us with an attractive solution to the initial puzzle. In section 1.4, I argue that the theory developed should be preferred over two main alternatives. I also briefly discuss some of the empirical consequences of the theory I put forward that could serve to test it. My hope is to show that the theory provides us with an interesting and explanatorily powerful way of characterizing our experience of the duration of long-lived events. The remainder of this introductory section elaborates on the distinction between short- and long-lived events that will be relevant throughout the discussion.

Short- vs. Long-Lived Events

The duration of an event is the sum of the durations of all its non-overlapping, proper temporal parts or, as I will call them, *slices*. So, while a part of an object and the whole object can have the same color—if, for example, the object is red all over—a slice of an event and the whole event cannot have the same duration. Furthermore, while one can see the color of an

object that is not wholly visible in one glance by seeing just a part of it, one cannot likewise experience the duration of a longer-lived event just by experiencing one of its slices.

Consider again THE DANCE SHOW. If the curtain is red all over, by sneaking into the theater and seeing a bit of the curtain Peter could get to see the color of the curtain. He could not, however, experience the duration of the whole dance by sticking his head into the theater and experiencing the duration of one of the dancer's pirouettes. For this, he needs to patiently stay in the theater and experience many more bits of the show. This suggests that if he experiences the duration of the whole dance at all, he experiences it differently from the way he experiences the duration of shorter-lived events whose duration he can take in at one glance.

Let a *short-lived* event be one whose duration can be taken in with one single act of looking, smelling, touching, tasting, or hearing and assume that these fall, roughly, within the milliseconds-to-a-couple-of-seconds range. Let a *long-lived* event be one whose duration is too long to be taken in this way; let's assume that they last for at least more than a couple of seconds. One of the underlying premises of this discussion is that we experience the duration of short- and long-lived events in different ways.¹

¹ This idea has been well-acknowledged within the experimental psychological literature, where it has been widely held that the way in which we experience durations in the millisecond-to-second range is not the way in which we experience durations within the second-and-above range. The difference is sometimes stated as one between *sensing* and *cognizing* duration. In his literature review, Grondin, for instance, writes:

Many researchers in the field of time perception—mainly those adopting a neuroscientific perspective [...]—have emphasized a distinction between intervals above and below 1 sec (Penney & Vaitilingam, 2008). *This distinction is based on differential pharmacological effects* (Rammsayer, 2008) *and on the fact that the processing of smaller intervals is sensory based, or benefits from some automatic processing, whereas the processing of longer intervals requires the support of cognitive resources* [...].

1.2 A Puzzle

Upon reflection, there is something puzzling about cases like THE SURPRISE PARTY and THE BORING MOVIE. Consider again the former: though the party was three hours long, you felt like it lasted just for one hour. Figure 1 below depicts the situation.

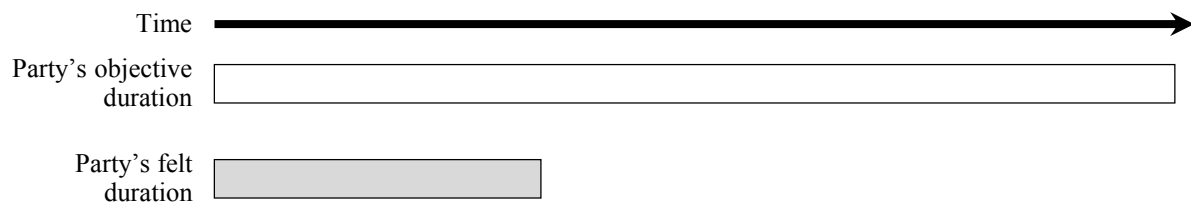


Figure 1. Surprise party's felt duration vs. objective duration

Consider, however, the short-lived events by means of which you experience the party. Examples of these are two friends shaking hands, everybody shouting “Surprise!” as you come in or the falling of a glass to the floor. Unlike the whole party, its short-lived events were not experienced as going by really fast. You did not, for instance, hear everybody’s voice as they shouted “Surprise!” as going so fast that you could hardly understand what was being said. Nor

Grondin, (2010), p. 564, my emphasis. As Grondin also makes clear, “[t]his 1-sec transition period remains somewhat arbitrary.” (Grondin, 2010, p. 564). Eagleman and Pariyadath make the same point in the following passage of the paper where they propose the neural energy model that will be discussed in the next chapter: “We focus here on timing mechanisms that underlie judgments at the ‘automatic’ or ‘direct sensation’ time scale, i.e. on the scale of tens to hundreds of milliseconds (*timing of longer scales, such as seconds and minutes and months are categorized as ‘cognitive’ and appear to be underpinned by entirely different neural mechanisms [...]*)”. Eagleman and Pariyadath, (2009, p. 1841, my emphasis). As the discussion in section 3.1 will illustrate, this distinction is also supported by phenomenological considerations.

did you see the glass that slipped through your fingers as crashing to the floor at a super-high speed. The party's short-lived events were neither experienced nor remembered as being experienced in the way in which a TV program would be seen if the fast-forward button were to be pressed.

The same occurs in cases like *THE BORING MOVIE*. Even if the movie seems to be taking a really long time, you do not experience it as a slow motion film: the characters, for instance, do not seem to be speaking ex—tre—me—ly slow—ly nor are the other short-lived events of the movie experienced as slowed down episodes.

Since it is by experiencing short-lived events that one gets to experience a long-lived event and the short-lived events in these cases are experienced as having durations that are roughly equal to their objective durations, one would expect the long-lived event to be also experienced as having a duration roughly equal to its objective duration. Yet the felt durations of the party and of the movie in the cases above were, respectively, much shorter or longer than their objective durations! Figure 2 illustrates this puzzle for the case of *THE SURPRISE PARTY*.

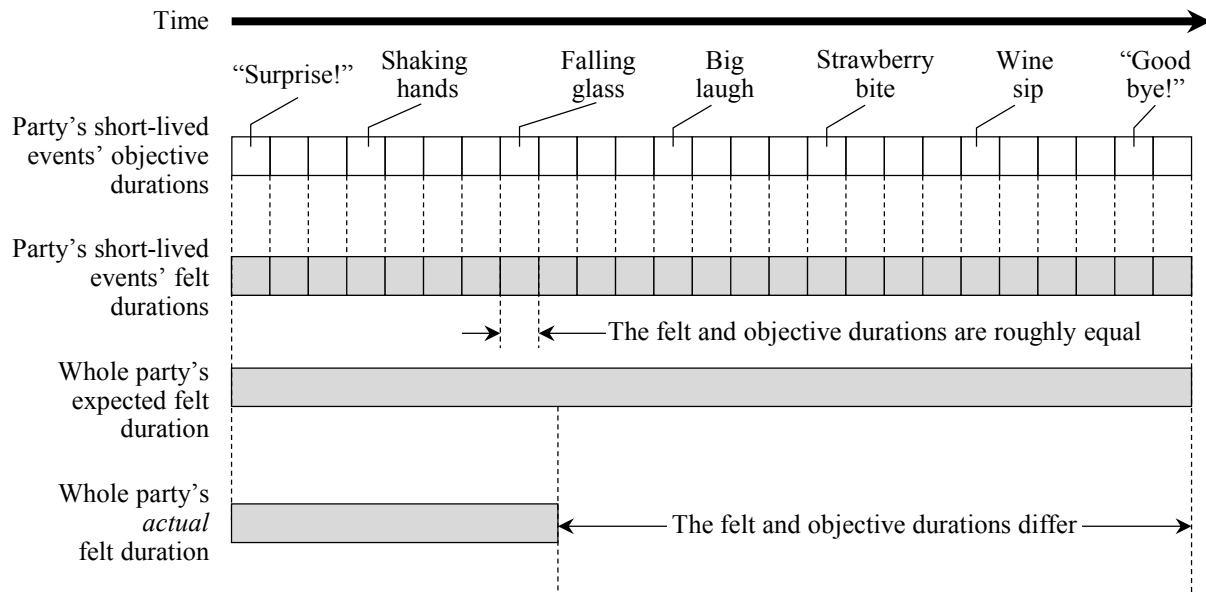


Figure 2. The puzzle

The puzzle thus consists in a part/whole incongruity in the experience of the event's duration. While for the long-lived event, its felt duration is much shorter than its objective duration (much longer in the case of *THE BORING MOVIE*), for the short-lived events—precisely those by means of which one gets to experience the long-lived event—their felt durations are roughly equal to their objective durations.

To solve this puzzle one needs to provide an explanation of why the whole party, but not its constituent, short-lived events, felt as if it flew by. One possible, though obviously false solution, for example, would be to claim that you were passed out for most of the party's duration. Had you become unconscious for two-thirds of the party, putting together the felt durations of the non-overlapping short-lived events that you did experience would yield a felt duration for the whole party of roughly a third of its objective duration. But of course this is not what normally happens during fun parties!

Another possible solution would be the claim that even though you were not passed out for two thirds of the party, you forgot that much. This, together with the claim that your experience of the duration of the whole party is the result of adding up the felt durations of the non-overlapping short-lived events that you remember, would serve to solve the puzzle. This proposal, however, is also unacceptable: while you forgot some of the short-lived events you experienced, you did not forget more than you would have forgotten if the party had been less fun. But had the party been less fun its felt duration would have been much longer!²

Instead of offering a direct solution to the puzzle, one might be tempted to deny that there is any *phenomenological* puzzle at all. The idea would be that while one may indeed experience the duration of a short-lived event—I may see the short flight of a bug across my computer screen as lasting for about a second—one could not experience the duration of the whole party: the party is too long-lived for its duration to be *experienced*. All one does is form judgments about the party's duration, which are not based on an experience of its duration but on something else.³ This 'solution' would thus aim at explaining away the phenomenological puzzle by denying that there is a real conflict between *experiences* of duration: all we really have is a clash between duration judgments.

There are, however, two problems with this 'solution'. First, it amounts to a straightforward denial of the datum we are trying to hold on to: it amounts to the claim that we do not really experience the durations of long-lived events. Second, this explanation does not

² For a further discussion of this proposal, see section 1.4.

³ In section 1.4, I will consider a proposal that takes duration judgments to be based on how features of the events experienced are encoded in memory.

really capture the phenomenon. For after you are told that you have been at the party for three hours and have verified this by looking at your watch, you will very likely form the belief that indeed three hours have passed since you arrived at the party. And yet it still feels like the party lasted for just one hour!

Compare this with looking at the now familiar illusion of the pencil under water. Even if, in looking at the scene, you do not go on to form the belief that the pencil is bent—you know this is an illusion—*the pencil still looks bent*. Likewise, even if you form the belief that the party lasted for three hours, it still feels as if you have been there for just one hour. *Feeling* or *experiencing* the party as having lasted just for an hour, thus, is distinct from the mere *judging* that it lasted this much.

A third feature of felt duration

Besides being susceptible to illusions and part-whole incongruities, the felt duration of a long-lived event exhibits a third feature: it allows for comparisons of *more or less* and of *how many*.⁴ There is something that it is like to experience an event as having twice, five times, or half the duration of another. Yesterday's party could have been experienced as lasting *twice* as long as last week's. One might also experience an event as taking more or less time than another. Today's walk, for instance, could be experienced as taking much longer than yesterday's.

With these in mind, let me turn to present a theory of felt duration for long-lived events. As explained at the end of the next section, the theory offers an attractive solution to this puzzle that accounts for all three features of felt duration.

⁴ As we will see in the next chapter, this is also the case for the felt duration of short-lived events.

1.3 The Theory

The theory will unfold in three main sections. First, I will characterize what I take to be the unit of felt duration, which I call *a quantum*. I will then offer a hypothesis about the objective duration of these quanta. Finally, I will use these two ideas in a model of felt duration of long-lived events, which I call *the subjective pacemaker for felt duration*.

1.3.1 The Unit of Felt Duration: A Quantum

Consider the following.

THE BERLIN WALL

Take some position such that, by standing on it and directly facing the Berlin Wall, one can take a good look at a small, colorful section of it. From this position, the paintings on the bricks are plainly visible and nothing other than this part of the wall is visible: one does not, for instance, also see a bit of the ground. Let this position be *the spot*. Consider someone, some years ago, standing at the spot and staring directly at the wall. Let her be *the viewer*.

By standing at the spot and looking straight, the viewer sees the colors, sizes, shapes, and other visible qualities of a part of the wall. She does not, for instance, see the whole wall at once, or as I will say, *in one glance*.

It is important to distinguish the qualities seen in a glance from the glance itself. Suppose all one sees in a glance is white. Seeing white is different from white. Seeing white is a visual experience of white. White, however, is the quality being seen, something that might or might

not be seen on a given occasion. More generally, the experiencing (visually or otherwise) of a quality and the quality experienced are distinct. I will also refer to the qualities of an object—items like the particular whiteness or roundedness of this or that figure on the wall—as its *features*.⁵

Typically, however, we do not just experience in one glance one quality but many. In one glance from the spot, for instance, the viewer can experience the various colors, sizes, and shapes of that part of the wall. We should also then distinguish the *act of experiencing* a collection of qualities—in this case, the glance—from the *collection of qualities* being experienced. A *glance* thus is a single act of visually experiencing some part of the scene before one; an act of seeing. Let *a look* be a collection of qualities that can be seen in one glance.^{6 7}

⁵ *Qualities* or *features*, thus, refer to particular items like the redness or roundedness of this or that figure on the Berlin Wall. The notions are intended to be non-committal as to what is the best metaphysical way of characterizing these items.

⁶ The idea of *a look* captures one of the senses in which we commonly use the phrase “a way something looks”. What we refer to with this phrase is to the particular look that the thing or, more generally, the situation encountered has under those specific conditions: from a certain distance, at a certain temperature, when having a dark background, etc. Under different conditions, a particular thing or situation might exhibit different qualities, and hence, under different conditions, the situation can have different looks. When, for instance, you say that the way the sunset looked yesterday made you think of the beach, you would be expressing the idea that the collection of qualities exhibited by yesterday’s sunset made you think of the beach.

⁷ Not all the qualities of an object or situation need to be part of its look. Objects might have qualities that we might not be able to experience. We must then distinguish the look of a thing or situation, which includes only those qualities *that can be taken in by a glance*, from the collection of *all* of its qualities.

Importantly, the qualities experienced in a glance, those that constitute the corresponding look, are not experienced as being unrelated to each other. Rather, they are experienced as composing a tight unity. They are all presented as being there together, as forming a cohesive, interrelated whole. Contrast the felt unity in the qualities of the section of the wall seen from the spot with the lack of it in the qualities seen through a journey of walking along the whole of the Berlin Wall while viewing all the graffiti painted on it.

To illustrate, consider again the look of the wall taken in by the viewer from the spot and imagine it has a red speck and a blue spot in its right and left extremes, respectively, as depicted in figure 3 below.

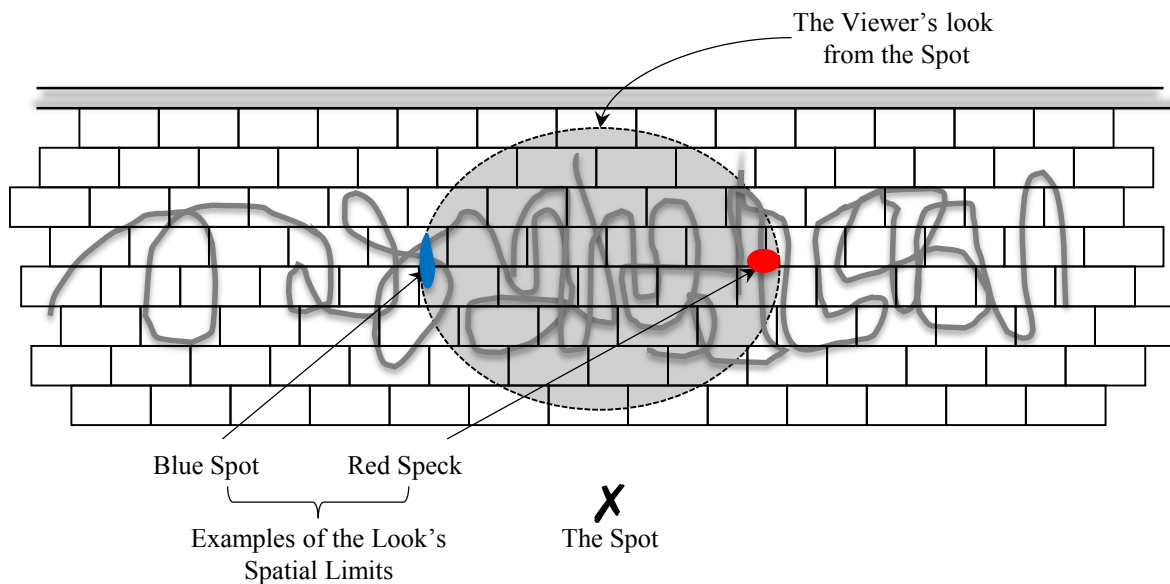


Figure 3. The Berlin Wall

Suppose now that we extend this look one foot on each side. We can imagine a creature that could take in this slightly wider look from the spot. By doing this over and again, we can

form a sequence that begins with the viewer and ends with a creature that could see the whole wall from the spot. Figure 4 below depicts some of these looks.

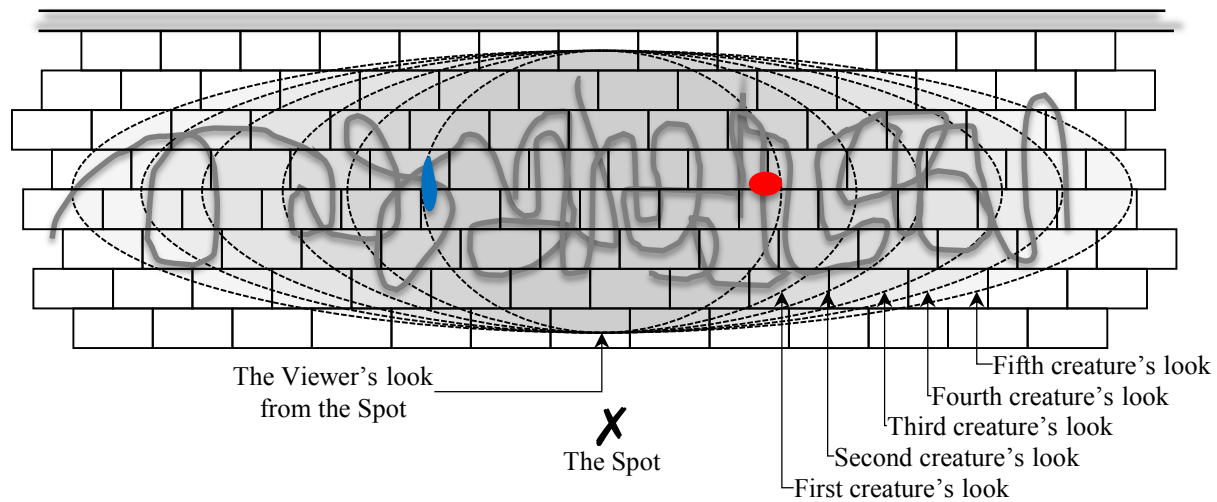


Figure 4. The wall's different looks, as seen by different creatures

Let us further stipulate that if any of these creatures were to walk along the wall and take in all of its visible qualities, they would all see the very same qualities of the wall.⁸ A yellow line on the wall, for instance, would be seen as having the very same shade of yellow by each of them. Despite this, for each creature in this sequence, her experience of taking in all the visible qualities of the surface of the wall will be different from the way it goes with the other creatures. The relevant difference shows up in the number of glances and corresponding looks that it takes each of them to see all of the wall's qualities.

⁸ This stipulation is needed because which qualities are parts of which looks might affect how they are seen. The redness of a spot on the wall, for instance, might not be seen in the same way if it is seen in a look that has blue in it. For the purposes of this dissertation, I will abstract away from these effects.

Consider, for instance, the last creature of our sequence. The viewer, by walking along the wall and glancing over it various times, and this creature, by exercising his super-powered vision and taking in at one glance all the visual qualities on the surface of the wall, both see exactly the same qualities of the wall. However, they see them differently; they take in different looks of the wall. While for the creature the qualities of the wall are all seen as being there side by side, forming one coherent, interrelated unity, for the viewer they are seen as forming many different such wholes. In one glance from the spot, for instance, the creature can, while the viewer cannot, see the colors at the far extremes of the wall. This is why if the viewer wants to compare the shades of red at the two extremes, she has to *remember* how the red at one extreme looked while she stares at the red at the other extreme. The creature need not use his memory for this: the look he takes in already has both shades of red in it.

The crucial thing to see is that the number of glances in which the qualities of an object are taken in *has effects on the overall experience of these qualities*. The features in the same look, those seen in the same glance, will typically be experienced as tightly united.⁹ Let this feeling of unity characteristic of the way in which the features in the same look are experienced be called *phenomenal tightness*.¹⁰

Note further that the look that the viewer takes in from the spot is both spatially extended and experienced as being spatially extended. The blue spot and the red speck in the look depicted

⁹ Most of the time the qualities that constitute the look are seen as tightly unified. In pathological cases, however, the degree of tightness with which these qualities are seen can be disrupted.

¹⁰ This felt unity is also exhibited when the viewer has an afterimage as of bright yellow spots: even if there is no yellow spot in the wall, the yellow spot that the viewer hallucinates is seen, say, as to the side of the red patch of the wall and as being part of the interrelated unity of which all the seen qualities seem to partake.

in figure 3, for instance, both occupy *and* are experienced as occupying the outermost spatial locations of this look. I will say that those features experienced as occupying the outermost spatial locations of a look are its *spatial limits*. The blue spot and the red speck in our example are thus the look's spatial limits.¹¹

A Sequence of Objects

Just as we can order possible creatures by the number of glances it takes them to see the entire length of a given object at a given distance, we can likewise order large objects by the number of glances it takes a given type of creature at a given distance from the object to see the full extent of those objects. Consider such a sequence for creatures like us from a vantage point of a few steps away. From that distance, we could see a small car or a large elephant in one glance and hence as within the space delimited by the spatial limits of the corresponding look. These objects will thus occupy the first position in the sequence. Seeing the full width of a soccer field when standing a few steps away from its sideline takes perhaps a minimum of fifteen glances. Hence, soccer fields will occupy the 15th position in our sequence. If seeing the entire Berlin Wall requires roughly the same number of glances as seeing the longest coast of Puerto

¹¹ Note that it is not enough to say that the viewer sees the blue spot and the red speck as spatially delimiting what is seen. For if she were to walk to the right or to the left, she would see other qualities as being spatially positioned further to the right or to the left of the red speck and the blue spot, respectively. In other words, she doesn't take the object seen—in this case, the wall—as being delimited by the blue spot and the red speckle. Rather, it is the look, the collection of features of the wall experienced as forming the same tight whole, what is experienced as being spatially delimited by these. Taking the red speckle and the blue spot as the spatial limits *of the look* can thus capture the way in which these qualities are experienced.

Rico from a few steps away then both will take the same position in the sequence, one further away from cars, elephants, and soccer fields.

The relevance of this sequence for our purposes is this. It delivers a rough ordering of large objects in terms of their relative lengths. Crucially, the ordering is arrived at *merely by considering the ways in which the objects are experienced*. That is, in forming the sequence, we exploited the experiential differences, illustrated through the Berlin Wall example, that arise from seeing the full extent of an object in different number of glances. Since, roughly, the larger the object is, the more glances it takes to see its full length from a fixed distance, the experiential feature associated with seeing an object in a particular number of glances—its phenomenal tightness—can serve to give us a comparative sense of how big the object is. Put differently, the spatial unit in terms of which the objects in this sequence are measured and ordered is subjectively defined: it is the longest section of the object that is typically seen, from a fixed distance away, in a glance by a given type of creature. We could, in effect, experience the spatial size of an object by having a sense of how many looks it has taken us to see the full extent of the object from a fixed distance apart. As will become clear, a similar idea will play a central role in the account of felt duration for long-lived events that I will develop.

Experiencing Temporal Features

In addition to colors, sizes, shapes and other such qualities, in a glance we also take in temporal features like brief changes, temporal orderings, and successions.

Consider again THE DANCE SHOW. Take one of the pirouettes towards the end of the performance and further suppose that from his seat, Peter can see the whole pirouette in one

glance: he can see the dancer turning as she speeds up and presses her arms towards her body and then opens them up again as she slows a bit to settle into a challenging position.

Apart from features like the orange of the dancer's suit or the shape of her figure, in the look taken in, Peter also sees some changes: the change in position along the dancer's own axis; the speeding up and down as she turns, and the stillness of her body as she takes the ending position. He also experiences their ordering: he sees the slowing of the turn as coming *after* its speeding up; the reaching out of her arms as *preceding* the movement in which she presses them against her chest; the ending posture as *the last in a succession* of rapid movements. All these temporal features are part of the same look of the dance Peter takes in.

Unlike the pirouette, however, Peter cannot see the whole dance in one glance. His experience of the dance does not exhibit the tightness of his seeing the pirouette. In this respect, his experience is like the viewer's experience of the whole Berlin Wall. Just as in one glance the viewer can experience some of the qualities of the wall—the colors and shapes of a part of it—Peter can experience some of the turns, jumps, and stretches of the dancers in one glance. However, taking in all of the visual features of the dance, just as seeing all the qualities of the wall, requires many glances from him.

As before, we can contrast Peter's experience with that of a creature who could see the whole dance in the way in which Peter sees a pirouette. For this creature, all the movements of the performance would be experienced as tightly united, as exhibiting phenomenal tightness. Unlike Peter, by sticking her head in and glancing once over the scenario, the creature could see the whole dance. She would not need to appeal to her memory to determine whether the opening

or the closing pirouette looks more impressive: she could determine this simply by looking at the scene before her eyes. Figure 5 depicts some features of the situation.

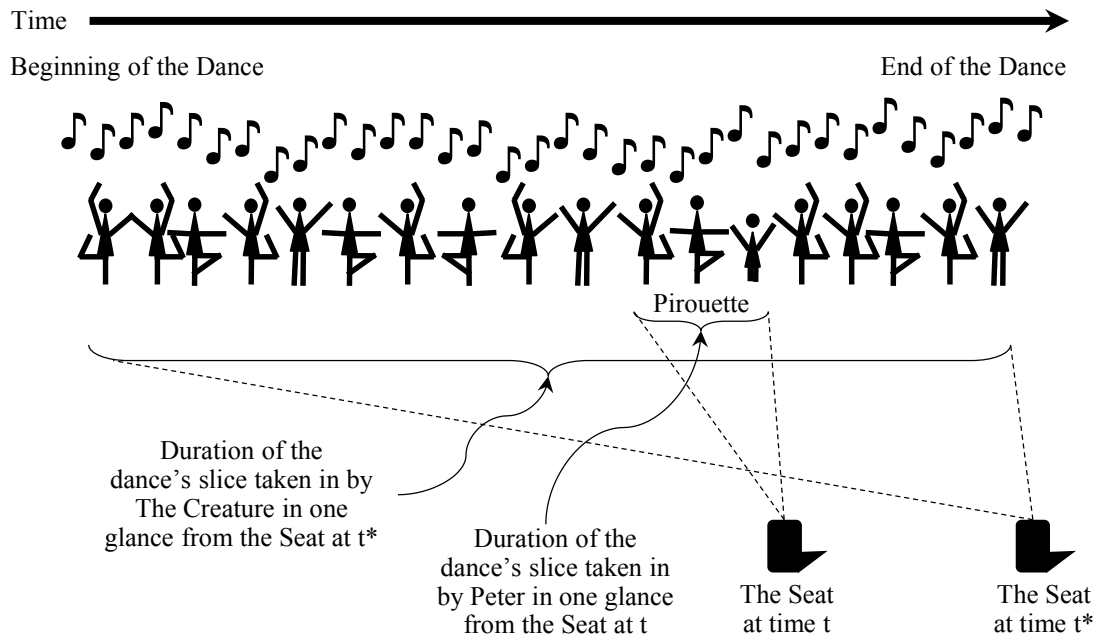


Figure 5. The Dance Show

A look, we have seen, stretches across space: its features form and are seen as forming a spatially extended stretch of the situation encountered. Likewise, a look also stretches across time: its features form and are seen as forming a temporally extended stretch of the situation taken in. To illustrate, consider again Peter's experience of the pirouette. Some parts of it are seen as happening earlier than others. Relative to one glance, some are seen as the earliest while others are seen as the latest. Let these be the look's *temporal limits*. The raising of the dancer's arms with which she begins the pirouette and the gracious kneeling with which she ends it could be, for instance, the temporal limits of one of the looks that Peter takes in. The rest of the

features are seen as occupying different temporal locations between these.¹² The features taken in through a glance, hence, are usually experienced as forming a spatially and temporally extended unit.

It is important to appreciate that looks are individuated by how the features of the situation encountered are *experienced* and not by the unity of the ordinary objects that are part of these situations, such as bricks, drawings, or walls. The spatial limits of the look of the Berlin Wall illustrated in figure 3, for instance, do not coincide with the boundaries of the bricks or the paintings on the wall. Rather, the look's spatial limits are whatever features are seen as lying at the outermost spatial boundaries of *what is taken in as being together, as unified*, whether or not this is where the spatial boundaries of the wall's bricks and painting may lie.

The same is true for a look's temporal limits: they need not coincide with the temporal boundaries of ordinary events like a dancer's pirouette or the ringing of a bell. As before, the look's temporal limits are rather given by those features experienced as occupying the earliest and latest temporal locations of *what is experienced as being together*, regardless of whether a whole event or just a part of it is experienced in this way. In order to get the idea across in a simple way, in considering the dance show above, we took it that Peter could see just one pirouette in one glance. As it now becomes clear, this need not be so: it could be that all Peter sees in one glance is a third of a pirouette or two and a half pirouettes. What determines the

¹² These temporal limits, like the spatial limits just discussed, are relative to looks. They are not simply the features experienced as being the earliest and latest seen. For before seeing this pirouette, Peter saw other slices of the dance and will see more afterwards as well. The dancer's raising of her hands and her kneeling on the floor are thus not the earliest and latest features seen by Peter. Rather, they are the earliest and latest features of the slice of the dance seen in *that glance*: they are the earliest and latest features of the particular look taken in by Peter at that time.

temporal length of looks, thus, are not the temporal limits of things like a pirouette *qua* pirouette but whatever is the longest-lived slice of the event experienced as unified, as hanging together.

The look Peter takes in, thus, includes temporal and non-temporal qualities alike. The dancer's turning and the orange of her suit, for instance, are experienced as being part of a spatially and temporally extended whole that exhibits phenomenal tightness. This should not be surprising at all; what would be strange would be for him to experience all the colors and shapes in one glance, and the movements, changes, and successions in a different one.

A Quantum

Similar considerations apply to the rest of our sensory modalities. Think of the difference between tasting a chocolate chip vanilla ice cream and tasting, separately, plain vanilla ice cream and chocolate chips; smelling a room scented with roses and cinnamon and smelling, separately, a room scented with roses and another room scented with cinnamon; having someone step on both of your feet at the same time and having someone step on one of your feet and then, after a bit, stepping on the other. These differences reflect whether the features are experienced in one or in various experiential acts: in one or in various tastings, smellings, hearings, or touchings.¹³

Just as with the case of seeing, through hearing, touching, tasting, or smelling, we also take in various temporal features. Think of feeling a finger slide across your arm, hearing the “dong” of your door bell as following the short “ding”, tasting the changing flavor of a strawberry-mint gum, or smelling the increasing smoke in the room that prompts you to call the

¹³ A tasting, a smelling, a hearing, and a touching are meant as the analogues of a glance, each corresponding to a different sensory modality.

fire department. Contrast the type of felt unity characteristic of these experiences with the lack of it in hearing a whole symphony, experiencing a five-course meal, a two-hour massage, or a twenty minute long perfume demonstration.¹⁴

Further, our experiences exhibit phenomenal unity across different modalities. Think of having a sip of wine while seeing the Sun setting and hearing the waves of the beach from afar. Or think of lying on the sand and seeing the clouds moving in the sky while feeling a few drops of water on your skin as it begins to rain. Experiencing these as unified, is distinct from experiencing each one on its own, as forming separate units.

In the case of visual experience, we said that a look is the collection of features—some temporal, some not—that can be taken in by a glance. Looks, we also said, are characterized by being experienced as tightly united, temporally, and spatially bounded wholes. A quantum is akin to a look but includes all the features taken in through *any sensory modality*. That is, a *quantum* is the collection of all the features of the situation encountered that can be taken in by any sensory modality in performing the more general analogue of a glance, namely, a single act of directed awareness. These features are also experienced as a tightly unified, temporally, and spatially¹⁵ bounded whole. A look is thus a visual quantum, something that can be taken in a single glance by beings with our kind of visual awareness.

¹⁴ Hearing a properly composed symphony or tasting a delicious five-course meal, for instance, might very well exhibit other forms of perceptible unity, just not the kind that we would contrast with hearing a few notes of the symphony or tasting the different flavors of a chocolate chip ice-cream. It is this type of unity, what we have called *phenomenal tightness*, that characterizes a quantum and which we are interested in here.

¹⁵ Some quanta are not experienced as being spatially extended. A quantum that consists solely of sounds like the one depicted in figure 6, for instance, would be experienced as a temporally but not spatially extended whole.

As with looks, the unity of a quantum is given by how the slice of the situation encountered by the subject is *experienced* and not by the unity of the ordinary objects or events that are being experienced. As figure 6 below illustrates, in entering a concert hall at the very end of a show, the last few notes and the beginning of the applause could be experienced as forming one of these experiential wholes despite the fact that the symphony began much earlier and the applause will still go on for a bit longer.

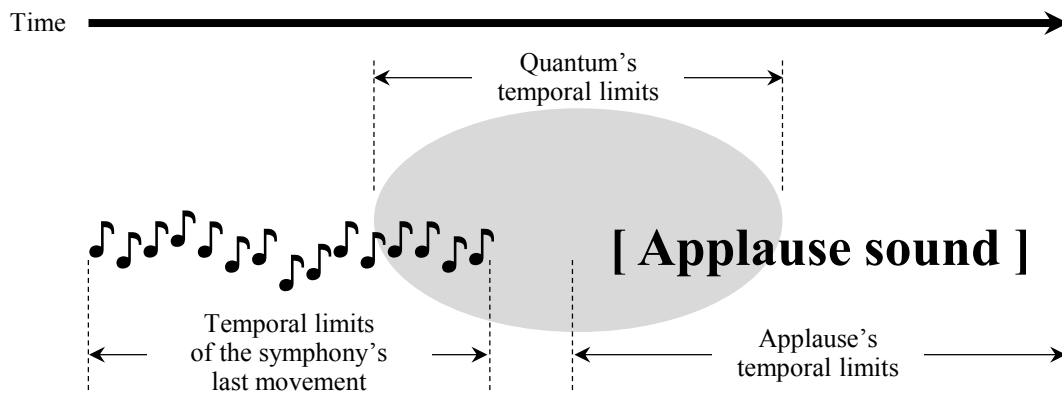


Figure 6. A quantum's temporal limits vs. an ordinary event's temporal limits

The considerations offered so far can be used to give a minimum sense to a slightly odd term often employed in the time-consciousness literature. Think of the *specious present* as the duration delimited by the earliest and latest temporal limits of a quantum.¹⁶ Just as the blue spot

¹⁶ James (1890), taking the term from Clay, understood the specious present as “the short duration of which we are immediately and incessantly sensible” (1890, p. 631). The specious present was also discussed by Brentano (1988), Broad (1923), and Husserl (1991), amongst others. My characterization of a quantum has been much influenced from reading the discussions of these authors. From these, Husserl is perhaps who influenced me the most. I also

and the red speck in the look from the Berlin Wall example are seen as delimiting a spatial section of the surface of the wall taken in by the viewer from the spot, the temporal limits of a quantum are experienced as delimiting the slice of the event that is taken in the same act of directed awareness. The specious present can be understood as the duration of the slice thus delimited.¹⁷

Consider again the slice of the dance taken in by Peter when he sees the pirouette. This slice includes the orange of the dancer's suit, the sounds from the orchestra, the smells of the theater, and the mint flavor from the gum Peter chews as he sees the pirouette. Add 250 milliseconds to this slice and imagine a creature that can take in this longer-lived slice from the seat as one experiential whole. For this creature, as we are imagining it, more features would be experienced as exhibiting phenomenal tightness, as being part of the same quantum. In addition to the above, in this quantum this creature would, for example, see some of the previous movements of the dance, feel the neighbor's elbow as he touches it just after the pirouette ends, and hear a few more sounds from the orchestra. By adding 250 milliseconds more to this slice

found Chisholm's (1981) discussion on Brentano's account of time consciousness very helpful. See also Dainton (2006).

¹⁷ I avoid speaking of the duration of a quantum as the specious present for three reasons. First, there is no one common notion of the specious present. Second, the specious present is usually presented in representationalist terms. Third, the specious present is sometimes understood as the duration of some 'internal' item. Thus, the specious present might be taken as the duration of an internal, mental representation or of the brain process that is taken to be either its supervenience basis or identical to it. In contrast, a quantum is not an internal object: it is a slice of the situation encountered, an object 'outside in the world', so to speak. Also, though a quantum could be understood in representationalist terms as some kind of representational content, I understand it instead as within an act/object account of experience.

and repeating this procedure over and over again, we can form a sequence of creatures that begins with Peter and ends with the creature for whom the entire dance is experienced as one experiential whole.

Once again, even if we stipulate that each of these creatures experiences the same features of the dance, there is still a difference in how these features are experienced. The difference lies in *how many quanta* it takes each creature to experience all of the dance's features: only those features in the same quantum will be experienced as bound tightly together. Contrast, for example, Peter's experience of the dance with that of the last creature in the sequence. For Peter, the features of the dance are taken in many pirouette-size bits; for this creature, they are experienced as in one very rich whole.

A Sequence of Events

For every long-lived event there will be a number of quanta it normally takes one of us to experience the event from beginning to end. As with spatial size, we can arrive at a rough ordering of the duration of events in terms of this number. The falling of a coin out of my pocket, the flight of a bug across my computer screen, or a few of a dancer's movements may be experienced in just one quantum. These will thus take the first position in the sequence. Seeing most of the runners of the New York City Marathon crossing the finishing line takes many more. In between these, there will be others. Hearing the full ring of my phone before it goes off, for instance, takes me just a couple of quanta.

As with length, the sequence so construed delivers a rough ordering of long-lived events in terms of their relative durations. Crucially, the ordering is arrived at *merely by considering the*

way in which these events are experienced. In other words, the unit in terms of which the events are measured and ordered in the sequence is subjectively defined: it is the longest-lived slice of an event that is taken in at a single glance or, more generally, in a single act of directed sensory awareness, or as I have called it, a quantum. Since, all else equal, the longer-lived the event is the more quanta it takes to experience the event's entire duration, the feelings of unity and temporal boundedness associated with an experienced quantum can serve to give us a sense of the durations of different events. In this way, the quantum could serve as the unit in terms of which we experience events as having different but comparable durations.

For such a sequence of long-lived events—ordered by the number of quanta needed to experience the long-lived event from beginning to end—to serve as an approximate ordering of the *objective* durations of these long-lived events, the following empirical hypothesis must be true.

1.3.2 Uniformity

UNIFORMITY	Usually, the objective durations of the quanta taken in by a given subject are roughly the same.
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If Uniformity were false, taking the duration of a quantum as the unit of felt duration would be disastrous. It would be like having a car that ‘measured’ the distance travelled with an odometer that randomly switched from meters to miles.

In the case of the dance show, for instance, Uniformity implies that Peter does not take in the dance in quanta of varying durations: he does not, for instance, experience the first hour of the show as forming a tightly unified whole while the rest of it is taken in in many ‘pirouette-

sized' quanta.¹⁸ Rather, he experiences the dance by taking in quanta of roughly the same objective durations. Figure 7 below offers an illustration of this.

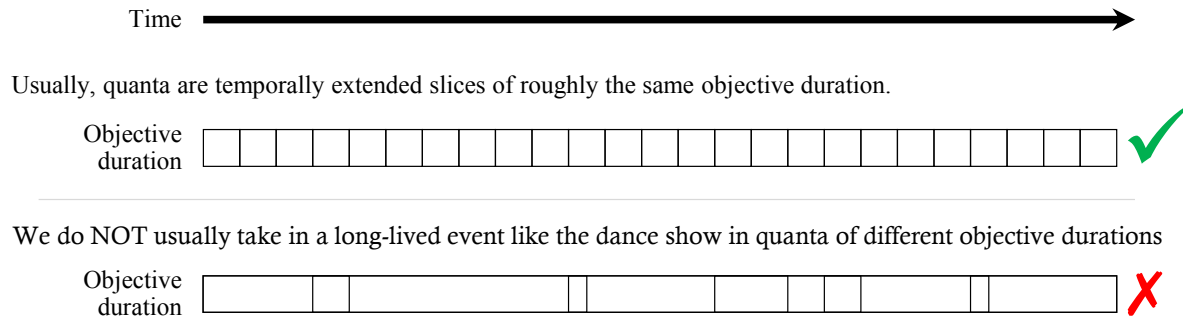


Figure 7. Uniformity

Given Uniformity, comparing the number of quanta that it takes any one of us to experience different long-lived events could, in effect, allow us to get a sense of how their objective durations compare to one another.

Let us now turn these thoughts into an actual model of felt duration.

¹⁸ Though I speak of 'pirouette-sized' quanta, recall that quanta need not fit in precisely a whole salient event like a pirouette. A subject's quanta could be such that they fit in, say, one and a half pirouettes. The important point is that, no matter how temporally extended they are, for a given subject, most of them are roughly of the same objective duration.

1.3.3 The Model: A Subjective Pacemaker for Felt Duration

The felt duration of a long-lived event, I will argue, could be the outcome of what I call *a subjective pacemaker*. In order to explain what a subjective pacemaker is, let me begin by briefly considering ordinary pacemakers.

Pacemakers

Let *a pacemaker* be a device that works by undergoing a certain type of process over and over again and counting the number of times that the process has been completed. Let us say that with each completed process a *tick* is produced. When a pacemaker is working well, the ticks are produced at a roughly constant rate. A pacemaker, thus, works by counting its ticks. Figure 8 below offers a schematic depiction of a pacemaker.

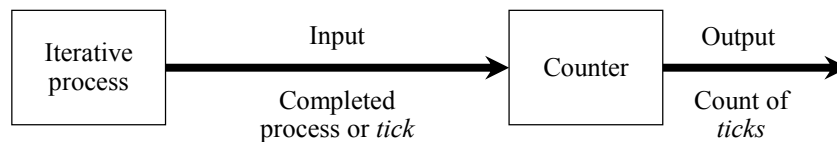


Figure 8. *A pacemaker*

The reason why a pacemaker is an attractive way of modeling felt duration is this. By comparing the number of ticks counted in a well-functioning pacemaker while different events take place we can determine how their objective durations compare to one another. If, for instance, more ticks are counted during one event than during a second event, then the first event

lasted longer. If the number of ticks counted during the first event is twice as big as the number of ticks counted during the second event then the first is twice as long as the second.¹⁹

Could we then say that the felt duration of a long-lived event is the product of a subpersonal pacemaker whose ticks are instances of a constantly recurrent brain process and that, thus, Peter experiences the duration of the dance show by having a subpersonal mechanism that counts the number of times this process takes place during the dance?

No, for even if a mechanism like this were indeed in place, it would not give us an account of what felt duration *is*, of what distinguishes it from a mere duration judgment.²⁰ Note that this model does not at all involve our experiences. But then, the very same account could be offered as an account of duration judgments that denies or remains silent about there being corresponding duration experiences. This is bad news for someone trying to vindicate the datum, that is, what we earlier called EXPERIENCE OF DURATION—the claim that, usually, we experience ordinary events as having durations and that these experiences provide the basis for our immediate judgments about the duration of those events. For in reporting that a long-lived event was experienced as having a certain duration, the subject could turn out to be like someone guessing the duration of her nap by saying the number that first pops into her mind or like someone estimating it based on the positions of the Sun. In either case, the theory that is supposed to account for our experience of duration would have us be, relative to the duration of

¹⁹ Ordinary pacemakers have been widely appealed to in modeling the felt duration of short-lived events. In the next chapter, I consider them in more detail.

²⁰ The subpersonal mechanism would not give us the type of account we are looking for even if you took the experience to be *identical* to the outcome of a subpersonal pacemaker. For the account would not be given in experiential terms.

the stimulus, zombie-like. That is, there would be nothing that is what it is like to experience duration. For this reason, this cannot be the complete explanation of the intuition that I judge that the party lasted for one hour *because of how it felt*, as opposed to because my brain operates in such and such ways.

One moral of this discussion is that the account of felt duration we are looking for should be distinguished from accounts of the organism's merely sub-personal mechanisms for keeping track of time. While these have various effects on a wide variety of processes of our bodies (e.g. neuron-firing, enzyme and hormone production, pregnancy) and some may or may not be what underlie our experiences of events as having durations, in so far as they do not involve our experiences, they will be of no interest to us here. If the datum is true, there should be a way of explaining what *felt duration* is that explains just how we experience events as having durations of different and yet comparable amounts.

As I explain below, by taking occurrences of a certain type of *experience* as producing the ticks, a *subjective* pacemaker takes us a step further: it offers us an account of felt duration that is given in experiential terms.

Subjective Pacemakers

Like other pacemakers, subjective pacemakers work by 'counting' ticks. The differences lie in what a tick is and in the sense in which they are 'counted'.

TICKS

Subjective pacemakers take occurrences of a certain type of *experience* as their ticks. Like with other pacemakers, a comparison of the number of experiences undergone while

different events take place could be used to determine how the event's durations compare to one another. What sort of experiences could serve as the subjective pacemaker's ticks? Had we had, for instance, a red dot blinking at a constant rate at the corner of our visual fields, we could have used these visual experiences as the ticks of our subjective pacemaker. But of course there is no such thing.

Unlike red blinking dots at the corner of our visual fields, experienced quanta can be the ticks of our subjective pacemaker. After all, to take in a quantum is just to experience some features of the situation encountered as already forming a tightly *unified whole*. Quanta, moreover, are not just experienced as wholes but, as we saw in the previous section, they are experienced *as temporally extended* wholes. But then, in experiencing quanta we would not only be experiencing that a unit has passed. We would also be experiencing time as having passed.

The idea of taking a quantum as the unit of felt duration is thus this: whatever slice of the situation is experienced as forming a quantum, that is, as forming a tightly unified temporally extended whole, that slice would also be experienced as taking roughly *the same amount of time*. In other words, the temporal extension of a whole quantum would always be experienced as being the same.

Finally, if Uniformity is true, besides being objects of our awareness and being experienced as temporally extended wholes, quanta have another feature that makes them suitable to be the unit of felt duration: they usually present us with slices of roughly the same objective duration. Thus, not only would quanta be experienced as taking the same amount of time: they would indeed, usually, take the same amount of time. But then, we could use the experiential feature characteristic of experiencing a quantum—the experience of being presented

with a temporally extended, tightly unified whole—to form a sense of how the objective durations of the different long-lived events experienced through these quanta compare to one another.

In order to have a subjective unit of duration, hence, there is no need for a red blinking dot on the corner of our visual fields or a constant beeping at the back of our auditory fields: experience itself is structured so as to do this work.

‘COUNTING’

The number of quanta ‘counted’ while experiencing a long-lived event determines how long the long-lived event is experienced as being.²¹ To ‘count’, however, is not to go ‘one, two, three, ...’ in our minds as quanta keep passing. It is instead to experience their number, to form an impression of their count.

Consider seeing a room with some people in it. Simply by glancing over the room you can form an impression of the count of people in it. You can tell, roughly, whether there are ten, twenty, a hundred, or fewer than six people in it. Note that in forming this impression you did not have to point to each person while thinking of the natural numbers in order. All you had to do was look into the room.

These impressions can also serve to make comparisons of more or less. Even if in glancing over the sky I cannot form an impression of the number of stars I see—there are too many of them—just by looking at the sky I may see the stars as being *more* than those I saw yesterday. I could even see the sky today as having roughly *twice as many* stars as it had

²¹ In fact, as will become clear as we proceed, the ‘count’ of quanta *is* the felt duration of a long-lived event.

yesterday. Thus, just as we can form impressions of colors, sounds, and shapes, we can likewise form impressions of numerosity or count, which allow for comparisons of *how many* and/or of *more or less*.

As with other objects of experience, we can form impressions of the numerosity or count of quanta involved in experiencing long-lived events. As will be discussed below, there are various factors that can interfere with how this impression is formed and which can thus give rise to particular kinds of illusions. What is important to see at the moment is that forming impressions of *how many* and of *more and less* need not be the product of a conscious cognitive process of going through the natural numbers with each passing quantum. Just as we can form an impression of the number of people around simply by looking into the room, we can likewise form an impression of the number of quanta simply by experiencing events. To ‘count’ quanta, thus, is to form an impression of their number, of their count. I will call an impression thus formed a ‘count’ of quanta.

Consider the quanta ‘counted’ in experiencing an event from beginning to end when our attention, emotions, stress, and other relevant factors are as normal as they ever are. Let this impression be *the characteristic felt duration of a long-lived event* of that objective duration.²²

We are now in a position to offer a first-pass explanation of what goes on when Peter comes out of the dance show and claims that he experienced it as lasting for an hour and a half. What happened is that Peter formed an impression of the count of quanta he experienced while in

²² If experienced quanta overlap, the felt duration and the characteristic felt duration of an event may rather be given in terms of the number of *non-overlapping* quanta that it takes to experience the event from beginning to end. For more on this, see chapter 3.

the dance show that is like the one he typically forms in experiencing hour-and-a-half-long events. In other words, the quanta he ‘counted’ during the dance show is like what he would ‘count’, under normal circumstances, during an hour-and-a-half-long event. This is how the felt duration of the dance is like the characteristic felt duration of an hour-and-a-half-long event: their ‘counts’ of quanta are very similar.

The felt duration of a long-lived event, thus, is this:

FELT DURATION FOR LONG-LIVED EVENTS The impression of the count of quanta formed in experiencing the long-lived event.

In other words, the felt duration of a long-lived event is the ‘count’ formed of the event’s quanta or, as we have also said, its ‘count’ of quanta.

Three Refinements

So far, we have a subjective pacemaker that works like this. It produces a tick every time a quantum is experienced. The ticks thus produced are fed into a ‘counter’ that accumulates them and produces as output an impression of their numerosity or count. To ‘count’ quanta is to produce such an impression. Figure 9 below offers an illustration of this.

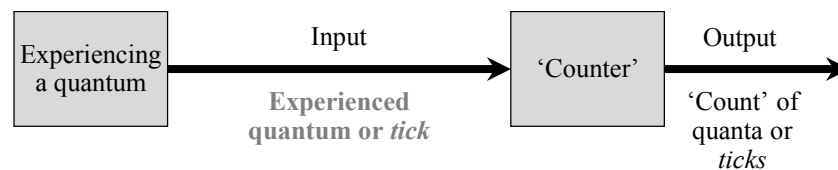


Figure 9. A subjective pacemaker for felt duration

This basic model, however, is in need of the following three refinements.

(a) What gets ‘counted’ are *noticed* quanta

Consider the following two situations.

A WALK WITH A FRIEND

You and your friend decide to take a walk in the countryside. To avoid getting lost, you walk along a fence, on the other side of which you can see a prairie. The fence is uniformly made: it has a post every four and a half feet. Throughout the hour-long walk, you and your friend engage in an old philosophical dispute. Still, the prairie is pretty enough to have you both always be staring, through the fence, towards the large surface of land.

WALK BY A FENCE ON YOUR OWN

Days later, you come back to the same place and, remembering the prairie, decide to take the same path on your own. Just as before, throughout the hour-long walk, you keep staring through the fence towards the landscape. This time no deep thought catches your mind. So even if you manage to entertain yourself with the mild beauty of the scenery, the walk is much duller than it was before. Halfway through the walk, you become slightly annoyed by the many posts of the fence. This makes you wonder whether you are in the same path from some days ago: you don’t recall having seen *that* many posts.

Two things are relevant about these cases. First, they suggest that in both walks you formed an impression of the number of posts seen on the fence. For even if during the first walk you never wondered how many posts there were, and in neither of them did you count them one by one, comparing your experiences of the number of posts in both walks made perfect sense.

Second, the cases also suggest that it is the number of posts that you *noticed*, and not simply the number of posts you *saw*, what affects the impression you formed of their count. This explains why when you were engaged in the conversation you ‘counted’ fewer. For in both cases your eyes were always open and looking in the right direction and, thus, presumably in both occasions you saw roughly the same number of posts. What differs is the number of posts you noticed. By being engaged in the conversation in the first walk, you directed less attention to the surroundings and, as a result, noticed fewer posts. Having less exciting things to focus on during the second walk the fence captured more of your attention. You thus noticed a larger number of posts.

Similarly, the number of quanta ‘counted’ in experiencing a long-lived event depends on the number of quanta *noticed* and not just in the number of quanta experienced throughout the event. As we will see by the end of this section, this feature of the model will be key in solving our initial puzzle.

Refining our basic model to account for this, we arrive at the model depicted in figure 10 below.

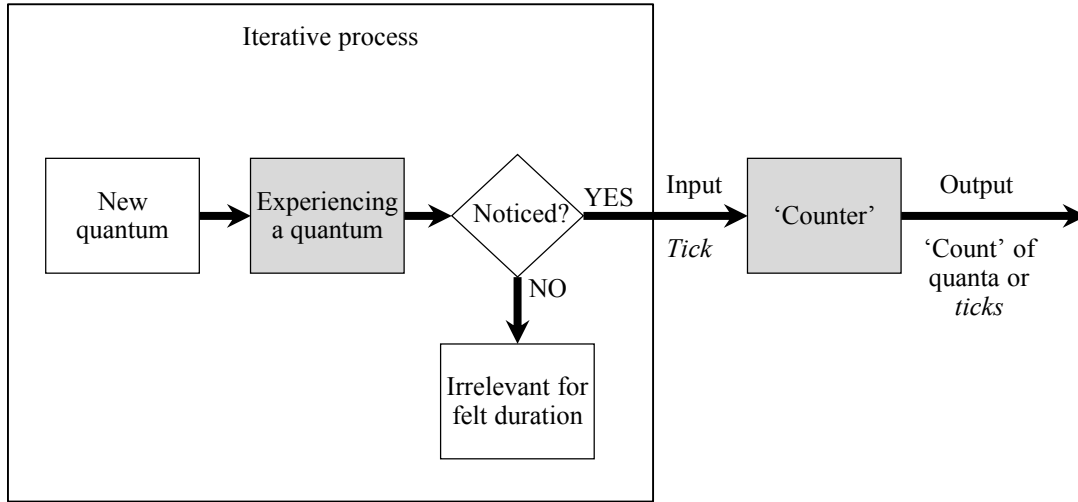


Figure 10. Noticed quanta are the input of the 'counter'

As shown, only noticed quanta are fed into the 'counter' and, hence, only these affect the impression formed of the count of quanta delivered as output.

But what is involved in noticing a quantum? In order to explain this, we first need to add one further refinement to our model. This addition will also serve to explain how the short-lived events taken in through a quantum can be experienced as forming part of a longer-lived event.

(b) The experiential feedback loop

The model depicted in figure 10 above involves, at any given time, *two* different experiences, which are the products of the processes that take place in the boxes highlighted in gray in the figure. The first is an experience of the latest quantum. The second is an impression of the count of quanta. The quantum experienced, if noticed, serves as the tick that goes into the 'counter', whereas the impression of their count is the output.

We do not, however, have two isolated experiences, one of the latest quantum and the other of a count of quanta. Rather, the ‘count’ of quanta affects how the current quantum is being experienced. This is what explains how, while experiencing a short-lived event, one can experience also the duration of the long-lived event of which it is part.

During the dance show, for instance, Peter may experience the short-lived events that form the latest quantum—say, the dancer’s turning and a few notes from the orchestra—as being part of a long-lived event that has been going on for, say, 45 minutes or so. What this would amount to in our model is this: Peter would experience the current quantum as one in a sequence of other quanta, where the size of this sequence is determined by his most recent ‘count’ of quanta for that long-lived event. Moreover, this ‘count’ of quanta is very similar to the one he usually forms when experiencing 45-minute-long events. That is, Peter’s ‘count’ of quanta, up until that point, is like the characteristic felt duration of a 45-minute-long event.

To account for this, we need to modify our model so as to have the ‘count’ of quanta generated as the output of the previous cycle *affecting* or *contributing to* the experience of the current quantum. That is, we need a feedback loop linking the ‘count’ of quanta from the previous cycle with the experiencing of the new quantum. Figure 11 offers a depiction of this.

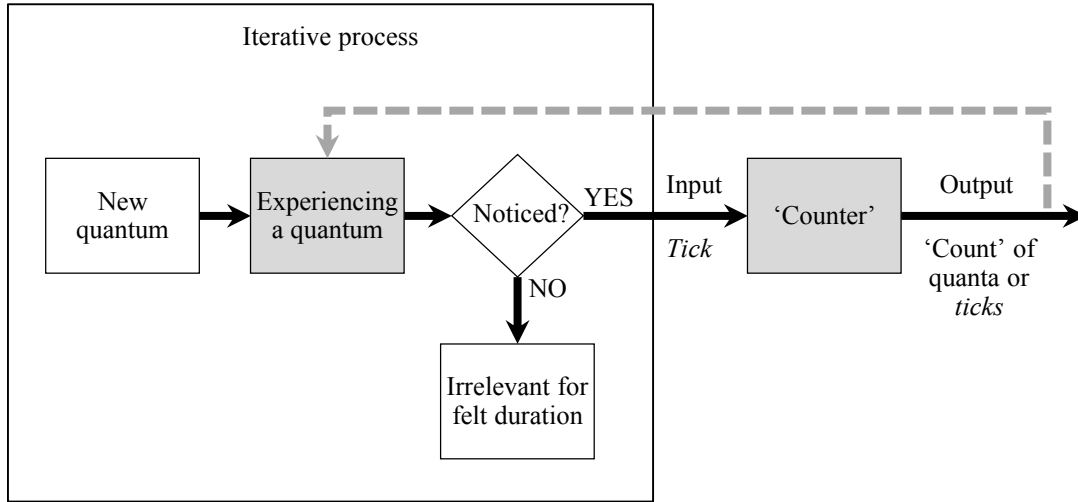


Figure 11. The 'count' of quanta from the previous cycle affects the experience of the current quantum

The feedback loop connects the output of the 'counter' from the previous cycle with the process that gives rise to the experience of the next quantum. The experienced quantum, if noticed, serves as new input of the 'counter'. The precise effect of this is that each quantum is experienced as the latest in a sequence of a size determined by the impression of quanta 'counted' so far, or as I will also sometimes say, the quantum is experienced as one more of those quanta 'counted' during the long-lived event.

To further illustrate, consider again being at a dance show and contrast the following two situations. In the first one, an alarm goes off 25 minutes after the dance begins. In the second one, the alarm goes off 50 minutes into the dance show. For simplicity, let us further assume that in each case all you experience as forming the corresponding quantum is the sound of the alarm: that is, assume that all that is heard is the sound of the alarm and neglect the effects on your

experience coming from the rest of your senses.²³ According to our model, even if in both cases all you take in is a qualitatively identical sound, there is still a difference in how the sounds in each of the cases are experienced. While in both cases you experience the sound as forming a quantum and you also experience this quantum as the latest in a sequence of quanta of a certain size, the size of the sequence in the first case is about half the size of the sequence in the second case. Figure 12 below offers a depiction of the two cases.

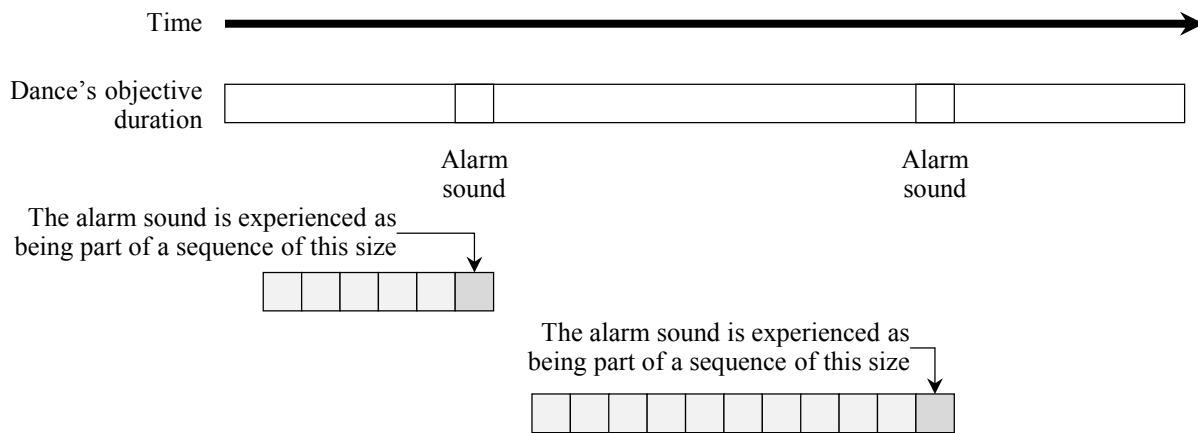


Figure 12. Experiencing a quantum as one in a sequence of quanta of a certain size

Since the impression of the count of quanta—just like the impressions of the number of people in a room—allows for comparisons of *how many* and of *more or less*, experiencing a quantum as one in a sequence of a size determined by this impression can, in the same way, be subject to such comparisons.²⁴ By comparing the impressions of the count of quanta in each case,

²³ Neglect also any effects on your experience coming from your emotional state, thoughts, and the like.

²⁴ We could see the effect of the impression of the ‘count’ of quanta on the experience of the current quantum as an experiential tag by means of which we temporally locate the short-lived events experienced in that quantum within the duration of the long-lived event of which they form a part.

thus, we can explain how the experience of the alarm in the second case differs from that of the first case. If both alarms had gone off during the same performance, by comparing the corresponding ‘counts’ of quanta, we could explain how you could have experienced the second alarm as going off *much later*, or about *half an hour later*, than the first.

With this in mind, we are now in a position of explain what is involved in ‘noticing’ a quantum.

(c) Experiencing versus noticing quanta

To experience a quantum, we have said, is to experience the colors, sounds, smells, and other features of the events and objects around us—those taken in the same act of directed awareness—as forming a tightly unified and temporally extended whole. *Noticing* a quantum involves more than this: it involves having an experience of the quantum *as the latest in a sequence of other quanta*, where the sequence is experienced as having a size determined by the quanta ‘counted’ so far.

The notion of *experiencing as* just appealed to is a familiar one. Consider the following well-known image depicted in figure 13 below.



Figure 13. Image of an old/young lady

We can see the object depicted in this figure *as a young lady* or *as an old lady*. Seeing it *as a young lady* differs perceptually from seeing it *as an old lady*. Likewise, experiencing a quantum *as one in a sequence of a certain size* differs perceptually from experiencing that quantum *as one in a larger or smaller sequence*.

We fail to notice an experienced quantum when the quantum is not experienced as being one more in the sequence of those quanta ‘counted’ during that long-lived event. In terms of our model, this happens when the feedback loop becomes ineffectual, when we do not experience the effects of the ‘count’ of quanta on the experience of the current quantum. Figure 14 offers a depiction of this.

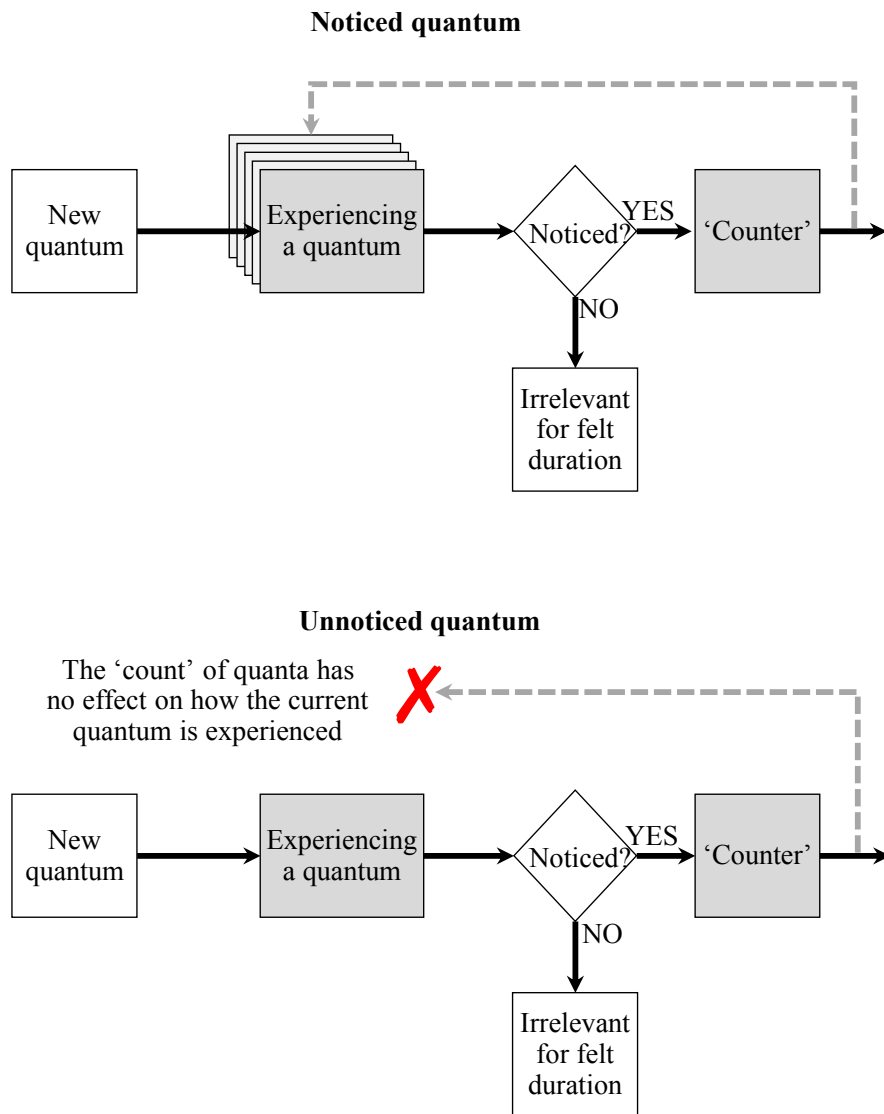


Figure 14. Noticed vs. unnoticed quanta

As the following example illustrates, this can happen when most of our attention is captured by the short-lived events we are experiencing.

Failing to notice a quantum

Consider the following. Suppose you set yourself to see all the paintings exhibited at a nearby, medium-sized gallery. Your plan is to spend no more than a few moments looking at each painting before moving on to the next. We can contrast the following two experiences.

SEEING AN AVERAGE PAINTING

You've been looking at the paintings in the gallery for a while and most of them are just barely interesting. You walk ahead to look at the next painting, which, like most of the others, does not capture much of your attention; it is neither especially appealing nor terribly plain. In looking at this painting, you can't help but see it *as one more of those seen during your visit*.

SEEING AN AMAZING PAINTING

As you continue to wander through the gallery, you come across a breathtaking piece.

From the moment you spot it, you become completely taken in by it. In this case, you do not experience the painting as one more of those you have seen during your visit.

You are so absorbed in it that you become unaware of having seen other paintings; you might even become momentarily unaware of being in an art gallery!

The relevant difference is this. Whether your impression of the count of paintings seen throughout the visit affects the experience of the painting you are currently looking at or not depends on how much attention the painting takes up. When the painting completely grabs your attention, you fail to attend to the 'count' of paintings seen. Because of this, you do not see the painting as one more of those you have seen during your visit. Note that your impression of the count of paintings might not be the only thing you become unaware of—you might be so

absorbed in the painting that you momentarily lose awareness of your mild hunger, your tired feet or, as in the example, your being in an art gallery.

The effect of directing more or less attention towards your impression of the count of paintings is similar to what happens in the more ordinary case of making a pain ‘go away’ by distracting yourself, for example, by watching a movie or having a friend over. While the movie or the conversation is really good, most of your attention is directed towards what you are hearing or seeing. As a result, the mild knee pain that has been bothering you all day may finally go away. As the movie or the chat becomes boring, your attention is freed again to focus on your knee and, as we have all witnessed with some regret, the pain very likely reappears.

This effect can also be illustrated with the depiction of the young/old lady in figure 13. Suppose the feather on the top part of the image starts grabbing more and more of your attention. In attentively looking at the feather, you might fail to see the rest of the image as depicting either a young or an old lady: you might just see the feather *as on top of an image*. When your attention starts drifting away from the feather, you might go back to see the image either as a depiction of a young lady or as a depiction of an old lady.

The idea is that what goes for paintings and pains goes for quanta and ‘counts’ of quanta. Usually, we experience a quantum as being one in a sequence of a size determined by the latest ‘count’ of quanta for that long-lived event. When we become absorbed in the short-lived events that constitute a quantum, we have less attention free to be directed towards the ‘count’ of quanta. As in the case of being absorbed by the features of a breathtaking painting, we thus fail to experience the quantum as one of other quanta we have experienced, as the latest in a sequence of a size determined by this ‘count’. What happens to the ‘count’ of quanta is thus what

happened to your pain while the interesting parts of the movie or of the conversation were taking place: it had no effect on your experience.

Failing to notice a quantum, thus, need not involve failing to notice the features of the short-lived events taken in through that quantum. What it involves is failing to experience the quantum as one more of those quanta ‘counted’ in experiencing the long-lived event, as the latest of the sequence formed by the quanta taken in during the long-lived event.

Furthermore, it is precisely because an unnoticed quantum has not been experienced as one of those quanta ‘counted’ that this very quantum does not get ‘counted’. Thus, unnoticed quanta do not contribute to the impression of the count of quanta. We can see this in the model depicted in figure 11 by seeing that an unnoticed quantum does not produce a tick: unnoticed quanta are not fed into the ‘counter’. The effect of this is that, keeping all else equal, as more quanta go unnoticed fewer get ‘counted’. Since the ‘count’ of quanta is what the felt duration of a long-lived event amounts to, the felt duration of a long-lived event with high proportions of unnoticed quanta will be shorter than the felt duration of a long-lived event of the same objective duration but with fewer unnoticed quanta.

Why, then, did the three-hour party feel like it was flying by while its short-lived events felt as if they had their normal durations? Why did the boring movie felt like it was taking so long, even if none of its short-lived events were perceived as slowed-down episodes? Let us put all these ideas together and offer a solution to our initial puzzle.

Back to the Puzzle: Illusions by ‘Miscount’

Take THE SURPRISE PARTY. Because the party is so much fun, you are taken in by a significantly larger number of the party’s short-lived events than you otherwise would. As a result, while experiencing these short-lived events your attention is not directed towards your ‘count’ of quanta and, hence, the quanta in which these short-lived events are taken in are not experienced as being part of those ‘counted’; or, as we have said, these quanta go unnoticed. What this means is that while you are experiencing the attention-grabbing events that compose these quanta you are unaware of the duration of the party. You are completely taken in by what is going on at that moment; you are not experiencing these events as adding on to the longer-lived event of which they form a part.

Furthermore, because these quanta are not experienced as being part of the sequence of ‘counted’ quanta, they themselves are not ‘counted’. Thus, in experiencing these quanta your ‘count’ of the party’s quanta will not increase. With a large enough number of engaging, short-lived events, the number of quanta ‘counted’ will thereby be significantly smaller than it would be had the party been less fun. But then, even if the party is experienced in roughly the same number of quanta as any other event of that same objective duration, during the party you ‘count’ *fewer* quanta. Figure 15 below offers a depiction of this solution to the puzzle.

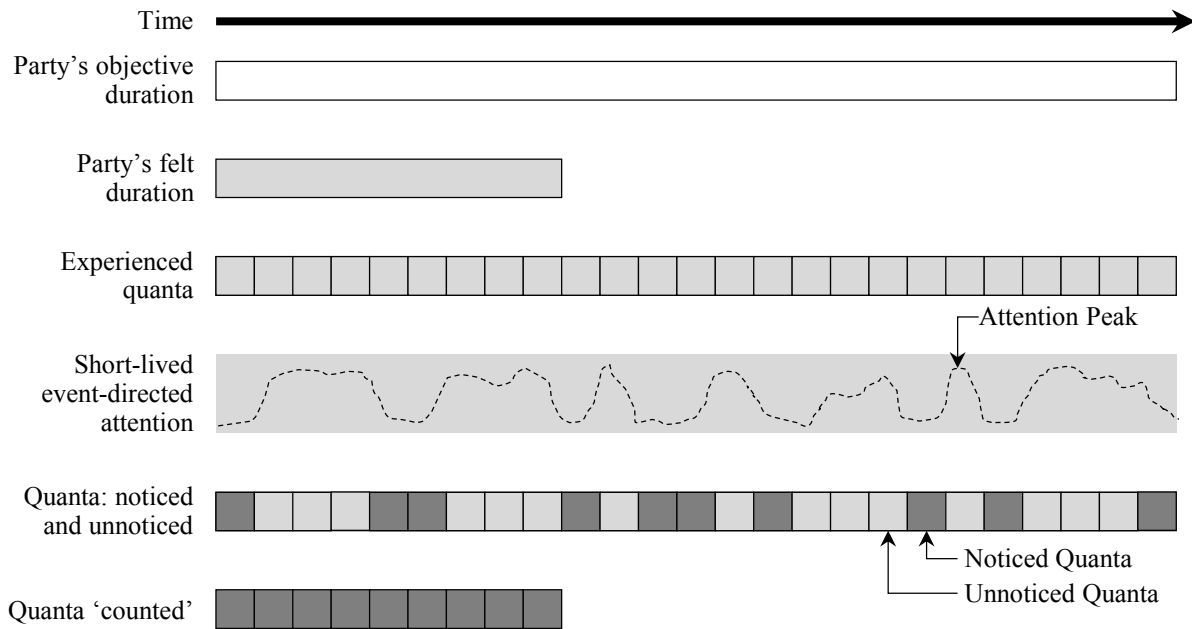


Figure 15. The unusually low number of noticed quanta is what accounts for the puzzle.

As shown in the figure, while the number of experienced quanta remains the same, the increase in the amount of attention directed towards the party's short-lived events results in a *decrease* in the proportion of noticed quanta. The result of this is a 'count' of quanta lower than it would be in a less exciting event of equal objective duration.

The opposite occurs in *THE BORING MOVIE*. Because you are not at all into the movie, you have more attention free to focus on the effects that the 'count' of quanta has on your experience of the short-lived events in the current quantum. As a result, even if you have experienced the usual number of quanta for an event of this duration, you notice more than you otherwise would and, hence, form an impression of a larger count: you 'count' more quanta.

Since the felt duration of a long-lived event just is the impression formed of the count of its quanta, noticing more or fewer quanta than usual, and hence, 'counting' more or fewer than

usual, explains why, while all of the short-lived events are experienced as having durations roughly equal to their objective durations, events like *THE BORING MOVIE* or *THE SURPRISE PARTY* feel as if they last, respectively, more or less time than events with the same objective durations. The abnormally low or high number of noticed quanta is thus what explains why, while the party felt like it was flying by, the movie felt like it was dragging along.

Let a '*miscount*' occur whenever we form an impression of a larger or smaller count of quanta than usual. 'Miscounts' of quanta, thus, are what give rise to the types of illusions and part/whole incongruities that characterize cases like *THE SURPRISE PARTY* and *THE BORING MOVIE*.²⁵ In the former, we have in an 'undercount' of quanta while in the latter we have an 'overcount'.

Note that this explanation does not need to assume that, under normal circumstances, we 'count' all the quanta we notice. All it requires is that under normal circumstances we 'count' a roughly fixed proportion of the noticed quanta. Illusions would arise when this proportion becomes significantly higher or lower.

Here is what we have achieved. We have offered a characterization of the experience of the duration of a long-lived event in terms of other experiences we already recognize, namely, experiences of tightly unified, temporally extended units or quanta and experiences of numerosity or count. With the account offered, we were also able to explain ordinary illusions like *THE SURPRISE PARTY* and *THE BORING MOVIE* and to say just what in them gives rise to the

²⁵ Attention need not be the only factor that produces 'miscounts' of quanta. Anxiety and certain emotions may be amongst other such factors. The model does not attempt to offer a complete explanation of what factors affect felt duration. Rather, it aims at providing an account of what felt duration is and a model in which to frame the more particular aspects of the phenomenon.

phenomenological puzzle we began with. In doing so, we made sense of the three features of felt duration identified earlier: its susceptibility to illusions, its susceptibility to part/whole incongruities, and the fact that it allows for comparisons of *more or less* and of *how many*.

1.4 Alternative Views and Some Empirical Predictions

Let us turn to briefly consider two main alternative accounts: the temporal resolution hypothesis and the memory hypothesis. As I explain below, the theory here developed has advantages over each of these. At the end of this section, I will briefly discuss some empirical predictions of this proposal that could be used to test it.

Temporal Resolution

According to the temporal resolution hypothesis, when we experience an event as lasting for more or less time than it does, what happens is that we experience, accordingly, more or less temporal features: the temporal resolution of our senses increases or decreases. To get a feel for this idea think of it as analogous to what happens when, by using a microscope, we sharpen our spatial resolution: spatial features that are too small to be seen with the naked eye become visible. In the case of duration, the effect of having an increase in temporal resolution is that we become able to experience changes that would otherwise be too fine-grained to be perceived, such as small shifts in frequency that usually go unheard. The contrary occurs, according to this theory, when we experience an event as lasting less time than it does. In these cases, our temporal resolution would decrease: we would experience fewer temporal features. A rapidly

flickering light that would normally be seen as flickering, for instance, would be seen as being constantly on.²⁶

This hypothesis, however, cannot account for our initial puzzle. For if what explains duration illusions is an increase in temporal resolution we would have to give up the intuition that in cases like *THE SURPRISE PARTY* or *THE BORING MOVIE* the felt duration for the long-lived event is, respectively, shorter or longer than its objective duration. The reason for this is that what would explain the unusual felt duration of the whole party or the whole movie would be that we became aware of, respectively, less or more fine-grained temporal phenomena than we do for events with similar objective durations. If this were so, there would have to be effects on the felt durations of the short-lived events in each case. But as we have seen, what gives rise to the puzzle involved in these cases lies precisely in the fact that the felt durations of the short-lived events remain unaffected. To the extent that these familiar cases are left unexplained, the hypothesis is defective.

The best the hypothesis could offer is an account of cases in which the short-lived events are also affected by the illusion. As will be discussed in the next chapter, however, even if restricted to these sorts of cases, the hypothesis faces serious empirical challenges.

The Memory Hypothesis

The failure of the temporal resolution hypothesis on empirical grounds was partly what drove Stetson, Fiesta, and Eagleman, the psychologists who tested the temporal resolution

²⁶ See Stetson et al. (2007). Thanks to Geoffrey Lee for drawing my attention to this paper.

hypothesis, to suggest that features of how we encode our experiences in *memory*, and not how the event is experienced, might be what explains inflated duration judgments. They wrote:

[W]e speculate that the involvement of the amygdala in emotional memory may lead to dilated duration judgments *retrospectively*, due to a richer, and perhaps secondary encoding of the *memories*. Upon later readout, such highly salient events may be erroneously interpreted to have spanned a greater period of time.²⁷

There are two ways of making sense of this idea, none of which can help us explain the datum. According to the first, features about how events are encoded *in memory*, not features about how they are *experienced*, are what ground duration judgments. According to the second, features of our memories would explain *only* the illusory cases. In veridical cases, our duration judgments would indeed be grounded by features of our experiences.

It should be clear by now why the first way of understanding the proposal, which may be called *the memory hypothesis*, cannot be the account of felt duration we are looking for. The reason is that it amounts to a denial of the datum, i.e. the claim that, usually, we experience the events we perceive as having durations and this provides the basis for our immediate judgments about the durations of those events. That is, it involves denying that the actual, contemporaneous experience of the event is what grounds the corresponding judgment about its duration. We should try to hold on to the datum.

The problem with the second way of understanding the proposal is that it is incomplete in a crucial respect: it is in need of an account of how, in the good cases, our experiences ground our duration judgments (it also requires an explanation of why this same account does not work

²⁷ Stetson et al. (2007), 3, my emphasis.

for illusory cases). This, however, is precisely what we would need if the datum were to be vindicated. Short of this, there is not much to say about this view.

Moreover, the memory hypothesis yields incorrect predictions. When we *recall* a fun party, we usually think of it as having lasted for a really long time. Yet, the party was experienced as flying by! This suggests that there are two *distinct* processes: one responsible for the way in which we *experience* the duration of the party and one for the way in which we *remember* it.

Like these two hypotheses, the theory offered here, if true, would have empirical consequences. Before concluding, let me briefly mention a way in which these could be used to test the theory.

Testing the theory through the Approximate Number System (ANS)

A cognitive mechanism, known within the psychological literature as *the approximate number system* or *ANS*, has been thought to be responsible for our perception and manipulation of approximate numerosity.²⁸ This system, for example, is thought to be responsible for comparing, adding, or subtracting sets of dots without going through a previous symbolization of their cardinalities in, say, Arabic numerals.²⁹ Moreover, items presented both simultaneously and

²⁸ Cordes, et al. (2001), Dehaene (1997), Feigenson, Dehaene, and Spelke (2004), and Cantlon et al. (2009), as cited by Gilmore, Attridge, Inglis, (2011).

²⁹ Cantlon et al. (2009) and Dehaene et al. (2008), as cited by Gilmore, Attridge, Inglis, (2011). As Gilmore, Attridge, and Inglis (2011, p. 2099-2100) write, it has been found that “[a]dults and children can compare, add, and subtract sets of dots or sequences of tones with above-chance accuracy”.

sequentially would be perceived and processed by this system.³⁰ Given this, we would expect the ANS to be precisely what is involved in producing the impressions of the counts of quanta; to be at least part of what is involved in the ‘counter’ of the subjective pacemaker for felt duration.³¹

The ANS has been thought to exhibit distinctive features, which might be used in testing the theory here developed. For instance, the accuracy of the ANS varies with the size of the quantities to be processed and is higher with smaller quantities.³² Also, its accuracy improves with a greater numerical difference between the items that are being compared.³³ If this is so, one

³⁰ Cordes, et al., (2001), Meck and Church, (1983), Revkin et al. (2008), Taves (1941), as cited by Chesney and Gelman (2012).

³¹ The idea that the perception of time and of numerosity are related has been suggested and supported within the psychological literature. For instance, the studies in Vicario et al. (2008) suggest that, as Agrillo, et al. (2010, p. 97) note, “small numbers biased estimation toward short durations whereas large numbers biased estimation toward long durations in a behavioral standard time comparison task.” Also, Meck and Church (1983) showed that “animals spontaneously encoded information about both time and number; furthermore, the psychophysical function representing the probability that subjects categorized an intermediate value was virtually identical when time or number was varied” (Agrillo et al. 2010, p. 97). In Agrillo, et al. (2010, p. 97) the idea that numerosity and duration are processed by the same system is challenged. As it is there noted, however, the results of this study are fully compatible with there being a unique system with various, qualitatively identical, parallel accumulators—one of which would be devoted to the processing of duration—with outputs that converged in a single system.

³² As explained in Gilmore et al. (2011), the quantities that are perceived and manipulated by this system are approximate, and their precision “is related to the size of the set—smaller quantities are represented more precisely than larger quantities”. See also Cantlon, et al. (2009) and Dehaene et al. (2008), as cited by Gilmore et al. (2011).

³³ This is called *Weber’s Law*. As explained by Piazza et al. (2013), what is suggested, thus, is that the ANS behaves in accordance with this law. See also Barth, Kanwisher, and Spelke, (2003), Cordes et al. (2001), Pica et al. (2004), as cited by Gilmore, et al. (2011).

would expect that, for instance: (i) the longer-lived the event is, the more illusory its felt duration would be; and (ii) subjects would be more accurate in comparing felt durations when their differences are larger.³⁴

It has also been held that the ANS develops sharply during childhood and, after reaching its peak, its performance exhibits progressively smaller improvements.³⁵ Thus, one would expect the differences in performance due to the ANS's developmental process to correlate with the levels of accuracy of felt durations of long-lived events during these periods. For the same subject, for instance, at least some types of illusions of felt duration for long-lived events would be expected to be more prominent during certain stages of the development of the ANS than during more stable periods. Subjects with developmental delays or with dysfunctional ANS would also be expected to exhibit abnormal patterns of illusions of felt duration during those years in which the ANS would typically develop.

1.5 Conclusion

Most of us know what it is like to see orange. In case of doubt, just hold a big, bright, ripe tangerine in your hands and look at it for as long as you need to. Time is by nature more slippery than this. I cannot lay a well-paced ten-minute walk in front of myself for my perusal. Even if I myself take the walk, every new step will wash away the previous one: no matter how hard I try,

³⁴ For some challenges faced by the current ways of measuring the ANS's performance, however, see Gilmore et al. (2011).

³⁵ For instance, see Piazza et al. (2013) as well as Halberda and Feigenson (2008) and Piazza et al. (2010), as cited in Piazza, et al. (2013).

I cannot have all of the steps in front of me as I can have the whole of the facing front of the tangerine. This, however, does not show that we do not really experience time; that there is no such thing as experiencing the duration of a ten-minute walk. It only makes its characterization more challenging.

What is it to experience the duration of a long-lived event? According to the theory developed, the short answer is this. It is to form an impression of how many quanta are involved in experiencing the long-lived event from beginning to end. In this way, a quantum provides us with the subjective unit of duration for long-lived events. Experienced quanta are thus the analogues of qualia like seen color, seen shape, felt texture, and heard sound for the case of the perception of duration. The passing of time has a feel to it, but it is not a novel color or shape or texture or sound. It is the passing of experienced units, and our temporal experience provides us with an impression of the count of these units or quanta.

Chapter 2:

A Quantum Theory of Felt Duration

for Short-Lived Events

2.1 A Classification of Duration Illusions

Consider the following.

THE SCARY ACCIDENT

Right after merging onto the highway, you see the line of cars in front of yours suddenly coming to a full stop. You press hard on the brake pedal, thinking that you won't be able to avoid a crash. Your car then seems to you to start slowly swerving to the right, which saves you from crashing into the car ahead. Unfortunately, a van from behind fails to see you in time and smashes into the back of your car, making it enter what feels like a slow spin that ends with the front of your car crashing into the concrete barrier. Luckily, apart from being terrified, everyone manages to get out of the accident without major injuries.

In extremely frightening situations like this, the subject's experience of the duration of the event seems to exhibit two features. First, the whole accident is experienced as lasting significantly more time than it did. Second, the accident seems to happen in slow motion. To appreciate this, let us contrast THE CAR ACCIDENT with THE BORING MOVIE considered in chapter 1 and offered again below.

THE BORING MOVIE

You entered the theater expecting a comedy. The movie turned out to be a flat, silly story, with not much going for it. It's the fourth time you check your watch: you can't believe time is passing so slowly! *What you've experienced as an hour has not really been more than 25 minutes.*

Like the whole accident, the whole movie seems to be taking a really long time. As noted in the previous chapter, however, the various scenes of the movie, unlike those of the accident, are not experienced as happening in slow motion. While the spinning of your car appears to be taking a very long time, the characters in the movie do not seem to be moving really slowly as they talk or walk around. Even if you feel you have been in the movie theater for much longer than you have, you do not feel as if something is wrong with the speed at which the film is being screened.

This difference can be put in terms of our earlier distinction between short- and long-lived events.³⁶ THE SCARY ACCIDENT and THE BORING MOVIE differ in this: while in both cases the long-lived event—the whole accident or the entire movie—is experienced as lasting much more time than it did, only the accident's short-lived events are experienced as having abnormally long durations.

³⁶ As presented in the first section of chapter 1, we can think of a *short-lived* event as one whose duration can be taken in with one looking, smelling, touching, tasting, or hearing. We can think of a *long-lived* event as one whose duration is too long to be taken in this way. Contrast, for instance, seeing the movements of the character's lips as she utters a couple of words with seeing the whole movie. You could not take in the whole movie like you take in this bit of the current scene; for this, you would need to patiently sit in the theater and take in the various short-lived scenes of the movie, one after the other.

Cases like THE SCARY ACCIDENT have been experimentally studied. A recent experiment that involved subjecting participants to a scary 31-meter free fall that lasted for about two and a half seconds, for instance, reported that the subjects overestimated the duration of their own free falls by an average of 36%.³⁷ The subject's quantitative estimations were accompanied by claims "that their fall had 'seemed to take a very long time'".³⁸

Drugs such as haloperidol have been thought to produce the opposite effect.³⁹ If this is so, while under the drug's effect, not only would the whole episode seem to last less time than it does, but its short-lived events would also be experienced as 'speeding up': lamp posts would be seen as flying by really fast as the subject walks towards them at a normal pace. Some studies

³⁷ As reported by Stetson et al. (2007), subjects were asked to compare the duration of their own free falls as they imagined it before it took place—but after they have seen other participants' free falls—and as they remembered it just after they experienced it. See Stetson et al. (2007, p. 2). Thanks to Geoffrey Lee for drawing my attention to this paper.

³⁸ Stetson et al. (2007, p. 3).

³⁹ As explained in Lee et al., (2009) "pharmacological studies indicate that time perception performance is highly sensitive to dopaminergic modulation. For example, dopamine agonists such as methamphetamine and cocaine produce lengthening of perceived time, whereas the dopamine antagonist *haloperidol causes subjective shortening of time* (Meck, 1996)", Lee et al. (2009, p. 180), my emphasis. Ogden et al. (2011) explain that the effects of haloperidol are found in time ranges below and above 1 second:

Rammsayer (1999) also suggests the processing of very brief intervals e.g. < 100 ms is thought to be based on a sensory timing mechanism which is largely beyond cognitive control (Rammsayer & Lima, 1991) whereas the timing of longer durations (1s and over) is thought to be mediated by cognitive processes (Rammsayer, 1999). Such suggestions were supported by Rammsayer (1999) who demonstrated that midazolam affected timing of longer durations (around 1000ms) but had no effect on timing of short durations (50 ms), *whereas haloperidol was found to affect the timing of both duration ranges.*"

Ogden et al. (2011, p. 260). See also Maricq et al. (1981), Maricq and Church (1983), and Meck (1996).

suggest that similar effects occur in patients with schizophrenia.⁴⁰ Alcohol has also been thought to produce these effects.⁴¹ I will simply refer to these cases as DRUG-INDUCED EFFECTS.

Like before, we can contrast DRUG-INDUCED EFFECTS with THE SURPRISE PARTY, which was considered in chapter 1 and is offered again below.

THE SURPRISE PARTY

Your friends organized a fun surprise party for you. Two hours into the party you look at the watch with astonishment: you can't believe it's that late! *It feels like the party has just started.*

Despite experiencing the party as lasting much less time than it did, none of its short-lived events were experienced as having abnormally short durations: you did not, for instance, see the glass that fell off the table as crashing to the floor at a super-high speed. The short-lived events of the party were not experienced as sped up; they were not seen as the short-lived events of a TV program would be if you were to press the fast-forward button.

⁴⁰ In a study where subjects were asked to differentiate between short (≈ 400 ms) and long (≈ 800 ms) sound signals, patients with schizophrenia took a significantly larger proportion of the long signals for the short ones when compared to control subjects, suggesting that the patients experienced the same events as lasting less time. As reported by Lee et al. (2009, p. 174), “[i]n the 400/800 ms condition, patients judged durations significantly shorter than did control subjects.” As they also pointed out, similar results have been found in a study using 200/800 ms as the reference stimuli (Elvevåg et al. 2003) and the results in Franck et al. (2005) also support these findings. See also Rammsayer et al. (1990) for a similar study performed for shorter time intervals.

⁴¹ In the studies reported by Ogden et al. (2011), a significantly larger proportion of the subjects who were given a high dose of alcohol reported that time seemed to pass faster than those subjects whose drinks had no alcohol. The intervals of time studied were all less than 1.5 seconds long. Thanks to Fiona Macpherson and Ian Phillips for pointing out to me that some studies have suggested that alcohol produce these effects.

Figure 16 classifies all four cases in terms of the types of events affected by the duration illusion and of whether the felt duration in each case is longer or shorter than the corresponding objective duration.

		Type of Events Experienced as Illusory	
		Only long-lived events	Both short- and long- lived events
Felt Duration	Shorter than usual	THE SURPRISE PARTY	DRUG-INDUCED EFFECTS
	Longer than usual	THE BORING MOVIE	THE SCARY ACCIDENT

Figure 16. Classification of duration illusions

While in all four cases the long-lived events' felt durations are illusory, only in THE SCARY ACCIDENT and DRUG-INDUCED EFFECTS are the short-lived events' felt durations illusory as well. Also, THE BORING MOVIE and THE SCARY ACCIDENT both involve illusory felt durations that are longer than their objective durations while for THE SURPRISE PARTY and DRUG-INDUCED EFFECTS the illusory felt durations are much shorter than their corresponding objective durations.

In the previous chapter, I put forward a theory of felt duration for long-lived events. This theory served to explain what the type of illusion underlying the cases in the left column consists

of. The aim of this chapter is to develop a theory of felt duration for short-lived events that can tell us what this felt duration is and explain the additional type of illusion involved in cases like THE SCARY ACCIDENT and DRUG-INDUCED EFFECTS.

I begin section 2.2 by considering proposals from the psychological literature and explaining how they differ from the kind of theory I aim to provide. Section 2.3 is devoted to developing this theory. Drawing on the notion of a quantum characterized in the previous chapter, we can express the main tenet of this theory as this: the felt duration of a short-lived event is how much duration of its corresponding quantum the short-lived event strikes one as taking up. As I go on to explain, this idea allows us to understand the duration illusions involving short-lived events found in THE SCARY ACCIDENT and DRUG-INDUCED EFFECTS as cases in which the duration of the corresponding quantum is, respectively, much shorter or much longer than usual. I call these *illusions by ‘compression’ or ‘extension’*. In section 2.4, I conclude by observing that while the theory here offered and the one developed in the previous chapter are distinct, they complement each other. Put together, they deliver a unified account of felt duration. This account proves fruitful: it provides different explanations of each of our four duration illusions that, as we have just seen, ought to be distinguished.

2.2 Psychological Models

In this section, I discuss three models for felt duration of short-lived events proposed in the experimental psychological literature: a sub-personal pacemaker and two state-dependent models, one based on attention and the other on levels of neural energy. After presenting some of the challenges that have been posed to these models from within the psychological literature, I

explain why even if the models could overcome these empirical difficulties, none could offer the type of account of felt duration that we are looking for.⁴² I finally suggest, however, that some features of these models could be taken up as insights in a theory of felt duration.

One clarification is in order. Sometimes these models are presented as accounting for duration experiences. Other times, however, they are presented as accounting only for duration judgments.⁴³ Despite this, since our interest is in felt duration, I will understand them as models of our experiences of duration *whether or not this is how they were intended by their proponents*. So even when I think that many times the models *are* intended as accounts of our experiences of duration, my discussion is not aimed at showing that they are right or wrong as they were proposed; I am not concerned with exegetical matters. The question instead is whether or not they *could* be offered as the explanation of felt duration that we are looking for. My claim is that they could not. The interest in discussing these models is then to bring out a crucial respect in

⁴² As Grondin explains, events between the 0.1- to 1-sec range have been the focus of much attention within the experimental psychological literature:

The 0.1- to 1-sec range has received quite a bit of attention because it covers (1) the debatable notion of indifference interval (around 700 msec)—that is, an interval in which there would be no tendency to overestimate or underestimate durations (see H. Eisler et al., 2008); (2) the highest sensitivity for tempo discrimination, located somewhere in the range of 300 to 800 msec [...]; and (3) the preferred tapping tempo (i.e., the spontaneous preferred in a tapping task), which is approximately 350 msec for children, 600 msec for young adults, and 700 msec for seniors (McAuley, Jones, Holub, Johnston, & Miller, 2006; see also Zelaznik, Spence & Doffin, 2000).

Grondin, (2010, p. 564, the footnote to this quote has been omitted). As was mentioned in footnote 1, “[t]his 1-sec transition period remains somewhat arbitrary.” (Grondin, 2010, p. 564). See also the rest of this section of Grondin’s review and footnote 1 from the first chapter.

⁴³ Most of the times the discussions go back and forth between talking of subjective duration, experiencing duration, appearing duration, estimated duration, and judged duration.

which a theory of felt duration that takes any of these forms differs from the kind of theory I am interested in offering.

Sub-Personal Pacemakers for Short-Lived Events

Prominent within the psychological literature are what I have called *sub-personal pacemakers*.⁴⁴ Though we briefly considered them in the previous chapter, these models have usually been targeted at short-lived events. For this reason, I discuss them here with more detail.

As explained in chapter 1 (section 1.3.3), the idea behind a sub-personal pacemaker is that some brain process is responsible for generating ticks at a roughly constant rate. The ticks produced during the presence of a short-lived event are counted. The number of ticks thus counted determines how long the event is experienced as lasting. In these models, the ticks are *only* sub-personally available.

Consider one of these models, an *information pacemaker*. According to this model, the brain's rate of information processing—which is assumed to be roughly constant—generates the ticks. When a fixed amount of information is processed, thus, a tick is produced. The number of ticks counted during the presence of a short-lived event, in turn, determines the event's felt duration. A comparison of the number of ticks counted by the pacemaker during each of two different events determines how the felt durations of these events compare to one another. Duration illusions are explained by arguing that factors like attention or emotion affect the brain's rate of processing information. Attending to a briefly presented event would, for

⁴⁴ See, for instance, Treisman (1963) and more recently Tse et al. (2004) and Ulrich et al. (2006). Cf. Grondin (2010). See also chapter 1, section 1.3.3.

example, increase the amount of information processed, which would then cause the pacemaker to count more ticks. This would result in an experience of the event as lasting longer.⁴⁵

Against this model, it has been claimed that our brains process different types of information at different rates.⁴⁶ For example, the processing rates for signals from different sensory modalities differ: it takes longer to process visual information than auditory information. Despite this, auditory and visual signals received within a short time window (approximately 80 ms) are experienced as in synchrony. For instance, if you utter some words in front of me, I process the visual and the auditory signals at different rates but experience the movements of your lips and the sounds you produce as in synchrony. This is so even when we can hear sounds that are just a few milliseconds apart from one another.⁴⁷

One might think that the reason for this is that the amount of information processed that counts as a tick varies across modalities. Thus, instead of a single pacemaker, what is needed is one *per sensory modality*, with the amount of information processed that counts as a tick varying

⁴⁵ Tse et al. (2004) explain that “[i]f attending to a stimulus boosts information processing of that stimulus, the counter would count more units, and subjective time would expand.” Tse et al. (2004, p. 1172). See also Eagleman et al. (2005).

⁴⁶ See Eagleman et al. (2005, p. 10371). This point is nicely made in Eagleman’s essay *Brain Time* on his website, <http://eaglemanlab.net/time> (accessed on Sept. 25th, 2012). The example is also taken from this essay.

⁴⁷ As Eagleman points out, this is why sounds and not light flashes are used as the *go* signals in short distance running competitions: our reaction is faster in the former case. Cf. Eagleman (2005) and <http://eaglemanlab.net/time> (accessed on Sept. 25th, 2012). The example is taken from his essay *Brain Time*, found in this website. On the timing studies, Eagleman refers back to Di Lollo, (1977). In Eagleman and Pariyadath (2009), it is also argued that sub-personal pacemaker models for short-lived events have not found support from neurophysiology studies.

for each.⁴⁸ According to some studies, however, the felt duration of a stimulus from one sensory modality can affect the duration that a stimulus from a different modality is experienced as having.⁴⁹ For the model to account for cross-modal effects like this, the various pacemakers would have to interact in complicated ways. This has been taken to cast some doubt on sub-personal pacemakers and motivated the proposal of alternative models.⁵⁰

State-Dependent Models

State-dependent models have been proposed as an alternative to sub-personal pacemakers. According to these models, there is no need for a counter: features of the patterns of our neural states can directly determine the felt duration of the short-lived event that serves as the stimulus.⁵¹ To illustrate, consider an attention-based model. According to this, the features of our neural states encoding the level of attention that is directed towards the stimulus are what determine the felt duration for that stimulus.⁵²

Attention-based models were thought to offer an attractive explanation of a commonly discussed phenomenon within this literature, the oddball effect. When a novel stimulus, the

⁴⁸ A proposal similar to this is mentioned in van Wassenhove et al. (2008, p. 1).

⁴⁹ In one of these studies, van Wassenhove et al. (2008) aimed at testing whether the stimuli from one sensory modality could affect the duration judgments of a different modality. As they write, the results suggest “the existence of multisensory interactions in the perception of duration and, importantly, [...] that *vision can modify auditory temporal perception* in a pure timing task.” van Wassenhove et al. (2008, p. 1, my emphasis).

⁵⁰ Cf. van Wassenhove et al. (2008, especially p. 8).

⁵¹ See, for instance, Ivry and Schlerf (2008) and Karmarkar and Buonomano (2007). For a discussion of these models, see also Grondin (2010, pp. 567-568).

⁵² Cf. Grondin (2010, pp. 565-568) and Eagleman and Pariyadath (2009).

‘oddball’, is presented in a sequence composed of repetitions of a different stimulus, the oddball is experienced as taking more time than any of the repeated stimuli, even when they all have the same objective duration.⁵³ The proposed explanation is that the novelty of the oddball attracts more attention. If the level of attention directed towards an object is what determines its felt duration, this would explain why the oddball appears to last longer. Some experimental results, however, tell against this. For if felt duration is determined solely by those features encoding the levels of attention then, contrary to what has been observed, the felt duration of the oddball should increase if the oddball is more attention-grabbing, for example, if it is a tarantula as opposed to a shoe.⁵⁴ Despite this, it has been shown that the two stimuli have the same felt duration.⁵⁵

A different, though related, proposal holds that what determines felt duration is not the level of attention encoded in the neural state but *the amount of neural energy* involved in experiencing the stimulus.⁵⁶ According to this proposal, it is the unpredictability of the stimuli,

⁵³ See, for instance, Pariyadath and Eagleman (2007), Eagleman and Pariyadath (2009), and Tse et al. (2004).

⁵⁴ See Pariyadath and Eagleman (2007) and Eagleman and Pariyadath (2009). As they argue, the experiments also tell against the hypothesis that the saliency of the object is what is relevant. The example is taken from Eagleman and Pariyadath (2009).

⁵⁵ In the case of an information pacemaker, since attention need not be the only factor affecting the pacemaker’s rate of information processing, it can be claimed that different factors are involved in different cases. For example, in Tse et al. (2004) it is argued that the oddball causes an increase in *arousal* that raises the rate of information processing. A consistent account of what are the relevant factors affecting the pacemaker and how they interact would still be needed.

⁵⁶ As explained by Eagleman and Pariyadath (2009), the idea is, roughly, that the felt duration of a stimulus reflects the size of the corresponding neural response.

something shared by the shoe and the tarantula, that explains why they both have the same felt duration.⁵⁷ Because the oddball is less predictable than the repeated stimuli, more neural energy is involved in seeing it and thus it is experienced as lasting longer.

The predictability of the object, however, cannot be the only factor determining the level of neural energy. For then, given that looming and receding oddballs are equally unpredictable, they should be experienced as having the same durations.⁵⁸ However, a looming oddball presented in a train of steady stimuli appears to last longer than a receding oddball, even if they all have the same objective duration.⁵⁹ This model would thus need to explain which further factors are involved and just how they interact to produce the required effects on the levels of neural energy. An account of exactly which neural responses involved are relevant would also be needed.⁶⁰ Other models explore the idea that the emotional level involved in the experience is

⁵⁷ Eagleman and Pariyadath (2009).

⁵⁸ See van Wassenhove et al. (2008).

⁵⁹ In van Wassenhove et al. (2008, pp. 6-7) it is reported that: “[S]ubjective time dilation was consistently found in auditory, visual and auditory-visual presentations for a visual stimulus increasing in size, and an auditory event increasing in frequency (Loom experiment). [...] Second, a decrease in visual size and auditory frequency (Recede experiment) did not lead to significant distortions of subjective time.” They also reported that “a looming disc embedded in a series of steady discs led to time dilation, whereas a steady disc embedded in a series of looming discs led to time compression” van Wassenhove et al. (2008, p. 1). They suggest that the *saliency* of the object is the major factor affecting felt duration.

⁶⁰ Eagleman and Pariyadath acknowledge this. See Eagleman and Pariyadath, (2009, pp.1846-1847). Other problems raised for state-dependent models is how they can work in noisy environments and how the dynamics of the neural patterns could speed up or slow down in cases of duration illusions. Cf. Eagleman and Pariyadath, (2009).

what is crucial.⁶¹ Levels of arousal and saliency of the object have also been thought to be relevant.⁶²

All of these proposals share a single strategy behind them: a certain factor—be it the amount of information processed, the level of attention encoded in a neural state, or the amount of neural energy involved in experiencing the stimulus—is either an input, an output, or a feature of a sub-personal mechanism. Each of these factors is different from, but thought to be strongly correlated with, the duration of the stimulus.

One advantage of this strategy is that it allows for an easy explanation of duration illusions: cases in which, as we have seen, the stimulus is experienced as lasting more or less time than it actually lasts. Indeed, the accounts are tailor-made for this. Since according to these models what determines the duration experienced is a factor distinct from but correlated with the duration of the stimulus, they can explain the illusions by offering a plausible explanation of why this factor and the duration of the stimulus come apart in these cases.

The main problem with these models, however, is that *no features of our experiences get to play any role in them*. This raises the following questions: how could any of these mechanisms account for what *felt* duration is, of what is characteristic of *experiencing* duration? Also, why would the experience determined by any of these mechanisms be an experience *of the duration of the stimulus* as opposed to an experience of the level of attention directed towards the stimulus, the amount of neural energy devoted to experiencing it, or whatever else is taken to be correlated with the duration of the stimulus? Moreover, why do any of these mechanisms

⁶¹ On this, see the section on emotions in Grondin, (2010, pp. 566-567).

⁶² van Wassenhove et al, (2008).

determine *any experience at all* as opposed to only a duration judgment? Nothing in these proposals allows us to give answers to these questions.

As discussed in the last chapter for the case of subpersonal pacemakers for felt duration of long-lived events, because these models offer us no reason to think that the proposed mechanisms ground our experiences of duration as opposed to either the duration judgments directly or an experience of something else that generates them, these same theories can and have been offered as accounts of duration judgments that deny or remain silent about there being corresponding duration experiences. That is, these very same explanations could be used to argue that, relative to the duration of the stimulus, we are zombie-like. In other words, there would be nothing that is what it is like to experience duration. This is bad news for someone trying to account for what is characteristic of *experiencing duration* as opposed to what could merely generate the duration judgments. For this reason, none of these models can be the complete explanation of the intuition that I judge the oddball to have lasted longer than the repeated stimulus *because of what I saw* (and not merely because my brain operates in such and such ways).

Some of the factors already discussed such as attention or emotion might still have a role to play in a theory of felt duration. They could affect the *experiential features* that give rise to an overall experience of an event as lasting for a particular amount of time. In the rest of this chapter, I aim at offering a theory of this form.

2.3. A Model of Felt Duration for Short-Lived Events

2.3.1 The Main Idea

A Spatial Analogy

To get a sense for the main idea behind the model, consider the following spatial analogy. Suppose you are looking at a section of a wall from a few steps away. The look you take in of the wall has two squared figures, one darker and four times larger than the other, as depicted in figure 17 below.

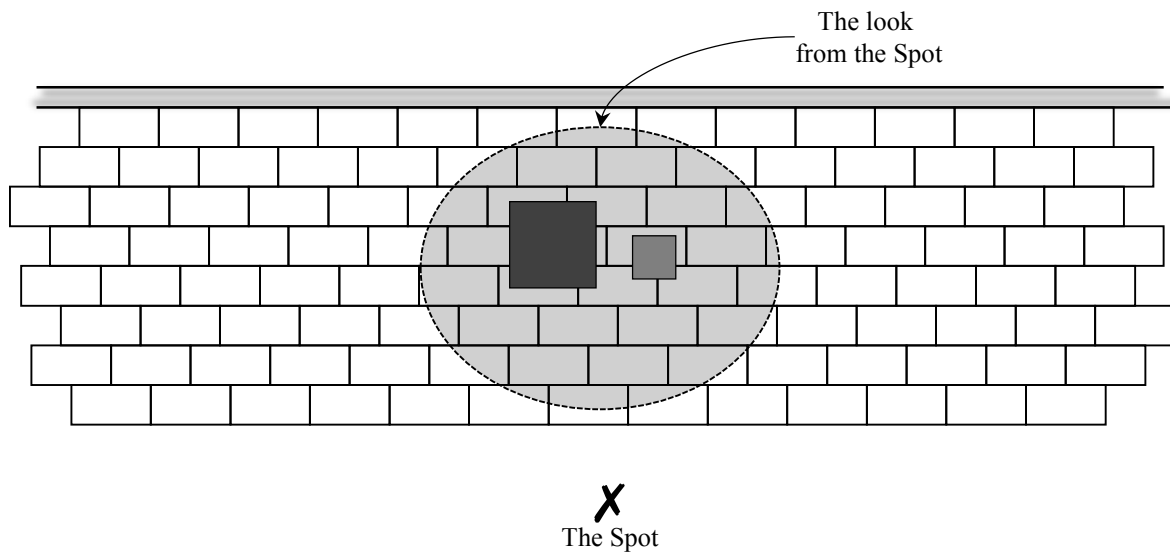


Figure 17. The look of the wall taken in from the spot

By taking in this look of the wall you see the two squared figures as having some extension or other. You also see the relative sizes of these figures with respect to one another: you see the dark square as being roughly four times larger than the lighter one. This, however, is not all of what you experience with respect to the figures' sizes. Besides this, you also

experience the sizes of these figures in a way that allows you to compare them with the sizes of other figures you are not currently seeing. This experience is what would allow you to see the figures as having increased or decreased in size even if their relative sizes with respect to one another stayed the same. To see this, consider the following situation.

Suppose the case is as before but that I had previously disassembled the section of the wall you are looking at and reassembled it on top of a movable device. With this device, I can move the section of the wall towards you while you blink so that when you open your eyes again the section of the wall is positioned just a few inches away from you. If I were to do this, your first impression after the blink would be as if the figures had expanded: while the figures will still be seen as maintaining their relative sizes with respect to each other, they will also be seen *as being bigger than before*.⁶³ Figure 18 depicts the looks before and after the wall is moved.

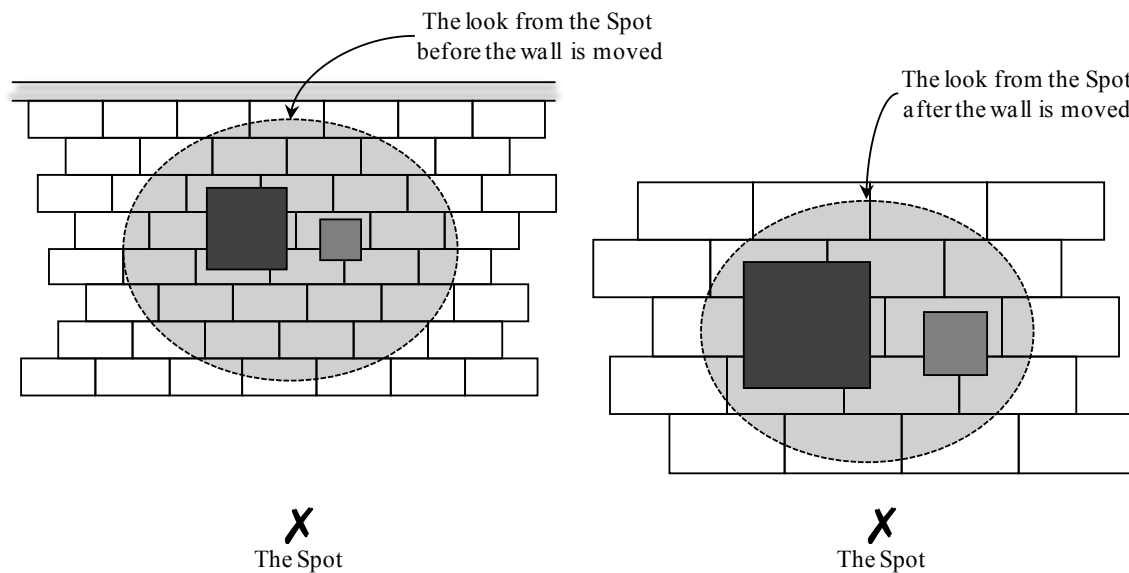


Figure 18. Seeing two squares on a wall from different locations

⁶³ I am imagining that depth cues are neutralized. Since we experience time as being one-dimensional, in the case of duration there is nothing corresponding to spatial depth.

Thus, even if in both cases the dark figure is seen as being roughly four times bigger than the light one, after the wall is moved, both figures are also seen *as being bigger than before*. Indeed, one could even see the sizes of the figures after the move as being about two times bigger than they were before. What in your experience allows you to compare the sizes of the figures before and after the move in such a way?

Whatever this is, it must have the following features. First, it must be present in both cases. Second, because you can see the sizes of the figures after the wall is moved as being bigger or as occupying about two times more space than they did before, it must also be something that allows for comparisons of *more or less* and *how much*. Third, because the figures' sizes did not really increase when the wall was moved, moving the wall must somehow make the experience become illusory. What could your experience of the sizes of the figures consist of so as to have these features?

The case suggests that what is experienced as the size of the figures really is their relative sizes with respect to that of the look in which they are taken in. In other words, it is *how much space the figures appear to be occupying from that of the look in which they are taken in*, regardless of what the look's size turns out to be. For it is precisely this relative size that increased after the wall was moved: before the move, the dark square took about one tenth of the space of its look while, after the move, the dark square took about a forth of the space of its look. This sudden change in how much space of their corresponding looks these figures are seen as occupying can explain why they are seen as having suddenly grown.⁶⁴ (Because the figures on a

⁶⁴ You might think that the reason why the figures look bigger is because we are increasing the resolution with which we see them. This hypothesis, applied to the case of duration, will be discussed in the next section.

wall don't just grow like this, you will very soon realize that the squares have their same old sizes but are being seen from a closer distance.)

The idea behind the theory of felt duration for short-lived events that I want to develop is analogous to this. In this case, the felt duration of a short-lived event is given in relation to that of the quantum in which it is taken in. What this means is that the quantum serves as the unit in terms of which the duration of a short-lived event is experienced. Before explaining this in more detail, it will be helpful to offer a brief reminder of what a quantum is.

A Quantum: A Brief Overview

The look of the wall taken from the spot is a spatially extended section of the wall that is experienced as such. Besides being spatially extended, a look taken in through a glance is also temporally extended. Think of glancing over a dance show and seeing one of the dancers make a gracious move. In the look you take in, you see some of the changes in the positions of the dancer's body. Or think of looking into a soccer field and seeing a player's shooting the ball into the goal. In this look, you take in the changes in the positions of the player's arms and legs and in the ball's location.

A quantum is like a richer look: it includes features taken in from sight but also from the rest of our sensory modalities—it includes shapes, smells, textures, sounds, and tastes. Like with

looks, the features taken in through a quantum form a temporally and spatially extended whole that is experienced as such.⁶⁵

Which features form part of a quantum is determined in the same way it is for looks: a quantum is composed of whatever features are experienced as tightly unified. In the previous chapter, I called this feeling of unity *phenomenal tightness*. To illustrate it, consider again the look depicted in figure 17 above (page 71). Now consider the looks depicted in figure 19 below.

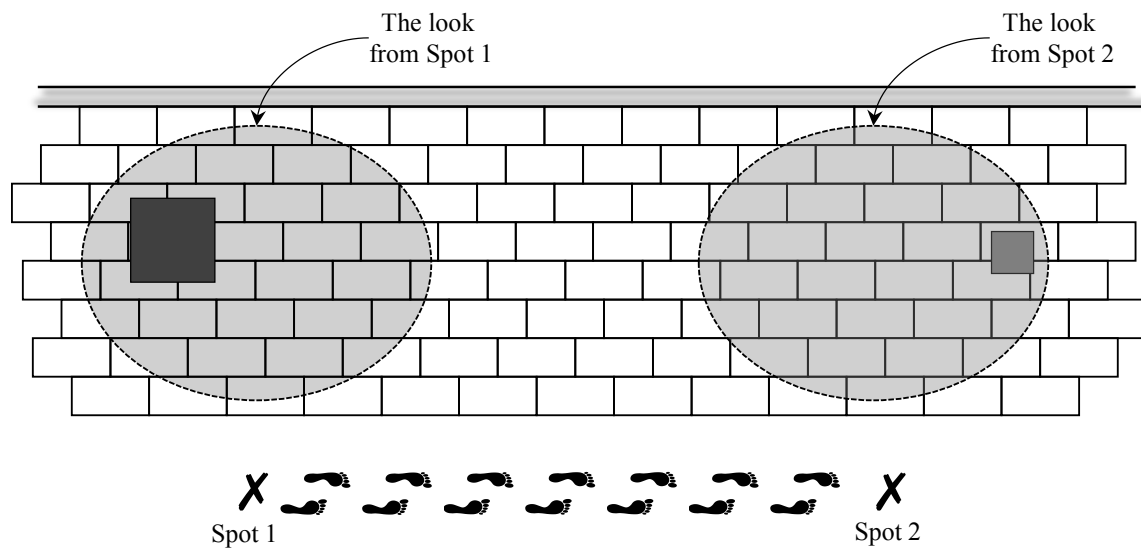


Figure 19. Seeing two squares on a wall in two different looks

Figure 19 depicts the same squares from figure 17 but this time located so far apart from each other on the wall that seeing them requires two different looks, one taken from one location (labeled *Spot 1*) and the other from a different one, a few steps away from it (labeled *Spot 2*).

⁶⁵ As mentioned in chapter 1, not all looks are experienced as being spatially extended. In those cases in which, for instance, sounds are the only things experienced, the quantum they form would be experienced as being temporally but not spatially extended.

Contrast the felt unity in seeing the two squared figures in the same look—as in figure 17—with the lack of unity in seeing them in two different looks—as depicted in figure 19.

A quantum, in sum, is the longest-lived slice of a situation that, when encountered, is experienced as forming a tightly unified, temporally and spatially extended whole. One of the underlying ideas of this model is that a quantum is the subjective unit in terms of which we experience the duration of a short-lived event.⁶⁶

Earlier, we said that a short-lived event is one whose duration can be taken in with a looking, smelling, touching, tasting, or hearing, whereas a long-lived event is one whose duration is too long-lived to be taken in this way. We can now restate this distinction in terms of quanta. A short-lived event is one that can be completely taken in within a quantum while a long-lived event is one that is too long-lived to be taken in this way.

Felt Duration for Short-Lived Events

Let us claim that:

FELT DURATION FOR SHORT-LIVED EVENTS The felt duration of a short-lived event is how much of its quantum's duration it strikes us as taking up.⁶⁷

To illustrate, consider the following case, which for simplicity focuses only on what is being seen and heard. Suppose you see a glass briefly sitting on a table and then being blown by the wind to the floor. Suppose further that you also hear someone rapidly tapping her foot on the

⁶⁶For a more thorough characterization of a quantum, see section 1.3.1 from chapter 1.

⁶⁷ It follows from this that while the felt duration of long-lived events are given in natural numbers, the felt durations of short-lived events will be given as fractions that range between 0 and 1.

floor. Each tap is equally spaced and you experience the fall as taking roughly six of them. The whole episode is experienced as taking a total of about twelve taps. Suppose further that you take in the whole situation in a quantum so that the falling of the glass struck you as taking up about half of its duration, as depicted in figure 20 below.

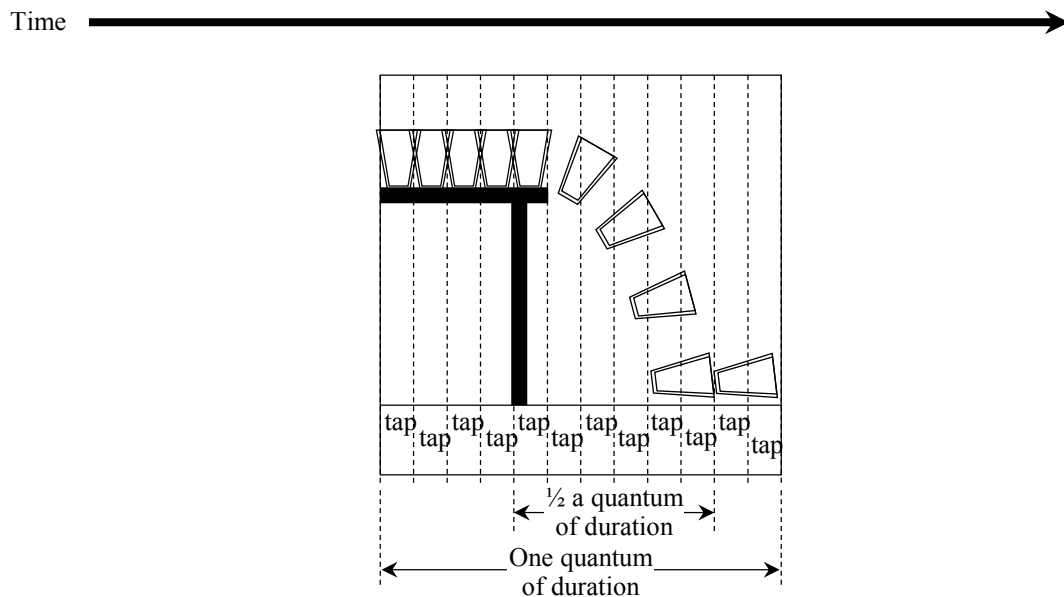


Figure 20. Felt duration of tapping and glass falling

Let us focus on what is experienced with respect to the durations of these short-lived events. By taking in this quantum you experience the fall of the glass and each of the taps as having some duration or other. You also experience the durations of the fall of the glass and of each of the taps relative to one another: you experience, for instance, the fall as taking as much time as six complete taps.

This, however, is not all you experience with respect to the durations of these short-lived events. If this were so, experiencing this episode would give you no sense whatsoever of how the felt durations of these short-lived events compare to those of other events you have experienced

before. For after all, their relative durations would have remained the same if they had all taken, say, ten times longer or just a fraction of the time they took. But your experience did not leave you in the dark as to whether these events took ten times as long, a small fraction of, or just as much as what they usually take! Thus, besides experiencing the relative durations of these events with respect to one another, you also experienced their durations in a way that allows you to compare their durations with those of other short-lived events you have experienced before or will experience after.

What does this experience consist of? According to our theory, what you experience is the relative durations of the short-lived events with respect to that of the quantum in which they are taken in. In other words, what you experience is how much of its surrounding quantum's duration these short-lived events strike you as taking up. Because the felt duration of every short-lived event is given in terms of that of a quantum, these felt durations are comparable with those of other short-lived events experienced in different quanta.

For instance, by experiencing the falling of the glass as taking up half a quantum long and because—let's assume—this is how long you usually experience a fall like this as taking, you can experience the fall as taking just as much time as it usually takes. Had the fall taken the whole quantum, you would have experienced it as taking twice the time it usually takes. In the same way, just after you finish hearing the tapping on the floor, you might hear someone clapping her hands at a constant rate and hear each clap as taking longer than, or even twice as much time as, what each of the earlier taps took. In this case, each tap would be experienced as taking one twelfth of a quantum while the clap must have been experienced as taking just one sixth.

Thus, the felt durations of different short-lived events, regardless of whether they are taken in in the same or in different quanta, allow for comparisons of *more or less* and of *how much*.

As I turn to explain in the next section, for comparisons between the felt durations of short-lived events taken in in different quanta to be veridical, the hypothesis called *Uniformity* and discussed in the previous chapter must be true. After explaining this, I introduce a second hypothesis that I call '*Elasticity*'. This hypothesis, I argue, would be needed to account for the illusory cases presented at the beginning of this chapter.

2.3.2 Two Hypotheses: Uniformity and 'Elasticity'

As explained in the previous chapter, the theory of felt duration for long-lived events there developed requires the truth of the hypothesis I called *Uniformity*, which I state again below.

UNIFORMITY	Usually, the objective durations of the quanta taken in by a given subject are roughly the same.
------------	--

This hypothesis is also required by our theory of felt duration for short-lived events.

To appreciate why this is so, suppose Uniformity is not the case and consider various instances of seeing a glass falling off a table, where the tables are always roughly of the same height. For most of these instances, the following will be the case. While the objective duration of each fall is roughly the same, given that Uniformity is not true, the objective duration of the quantum in which each fall is taken in will be significantly different. But then, the relative duration of the fall with respect to that of the quantum will also significantly vary in each case.

And since the felt duration of a short-lived event just is how much of its surrounding quantum the fall strikes us as taking up, the fall's felt duration will also vary in each case. This, however, is not how the different falls are experienced: most times I see a glass falling off a table of a particular height, I experience the fall's duration as taking roughly the same amount of time.

You can check this by performing the following little experiment: take a coin out of your pocket and let it fall to the floor while looking at it. You experience the fall as taking a small amount of time. If you do this again, this fall will be experienced as having roughly the same duration. And this will be so for almost every time you see a coin fall out of your pocket: your coin-falling-from-your-pocket experiences are never sped up or slowed down relative to one another. And the same is true for most experiences of different tokens of the same type of short-lived event. Typing my name on my laptop's keyboard at the usual pace, for instance, is almost always experienced as taking the same amount of time. What this means is that, if the theory is correct and there are no illusions involved in these cases, the quanta in which different short-lived events are taken in must have roughly the same objective duration. But this is just to say that, if the theory is right, Uniformity must be the case.

Uniformity, hence, is required to make sense of the fact that we usually experience the durations of different instances of the same type of short-lived event as having similar durations. Likewise, Uniformity is required to make sense of the accuracy in our comparisons of the felt durations of short-lived events taken in in different quanta. But, what accounts for the fact that sometimes these comparisons are misleading? In other words, what allows for duration illusions of short-lived events?

'Elasticity'

Though quanta usually have the same objective duration, on certain occasions, they 'compress' or 'extend'. To say that a quantum 'compresses' or 'extends' is to say that its duration is shorter or longer than that of a typical quantum. Consider, for instance, seeing a dance show. If in a typical quantum you take in just one pirouette of the dance, you can think of an 'extended' quantum as one in which you take in the pirouette and some other movements. Conversely, think of a 'compressed' quantum as one in which you cannot take in the whole pirouette: maybe you can see only a third of it.⁶⁸ Figure 21 illustrates this.

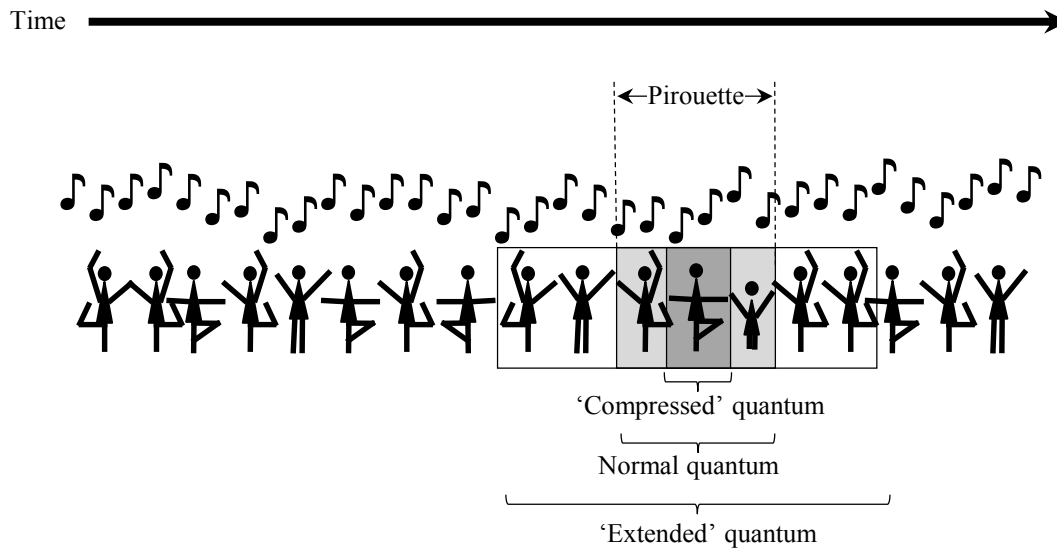


Figure 21. 'Compressed' and 'extended' quanta

⁶⁸ Ian Phillips recently pointed out to me that in Lockwood (2005) a similar hypothesis is discussed, which is called *Elasticity*. The two hypotheses, however, differ in at least the following crucial respect: unlike mine, Lockwood's hypothesis involves a commitment to a version of the temporal resolution hypothesis, discussed towards the end of this chapter. See Lockwood (2005). Thanks to Ian Phillips for the reference.

This claim, also about the objective duration of quanta and fully consistent with Uniformity, can be expressed as follows.

‘ELASTICITY’ On certain occasions, the objective durations of the quanta taken in by a subject are significantly longer or shorter than usual.

Note that none of these hypotheses require the quanta of *different* subjects to have the same objective duration. Uniformity and ‘Elasticity’ are both claims about the objective durations of the quanta *of the same subject*.

As I turn to explain, experiencing short-lived events as speeding up or slowing down consists in experiencing them in ‘compressed’ and ‘extended’ quanta.

2.3.3 Back to Duration Illusions: THE SCARY ACCIDENT and DRUG-INDUCED EFFECTS

There are two effects of having ‘compressed’ and ‘extended’ quanta: one over the felt duration of short-lived events and one over the felt duration of the long-lived events. These effects are what account for the types of illusion that characterize THE SCARY ACCIDENT and DRUG-INDUCED EFFECTS. Let us first consider the former.

Effects on Short-Lived Events

Suppose I had two pills: the *slow pill* and the *fast pill*. The slow pill ‘compresses’ your quanta while the fast pill ‘extends’ them. Consider now your experience of the dance show when no pill is taken, when the slow pill is taken, and when the fast pill is taken. Figure 22 below

compares the objective durations of the quanta and the short-lived events of a section of the dance show for each of these cases.

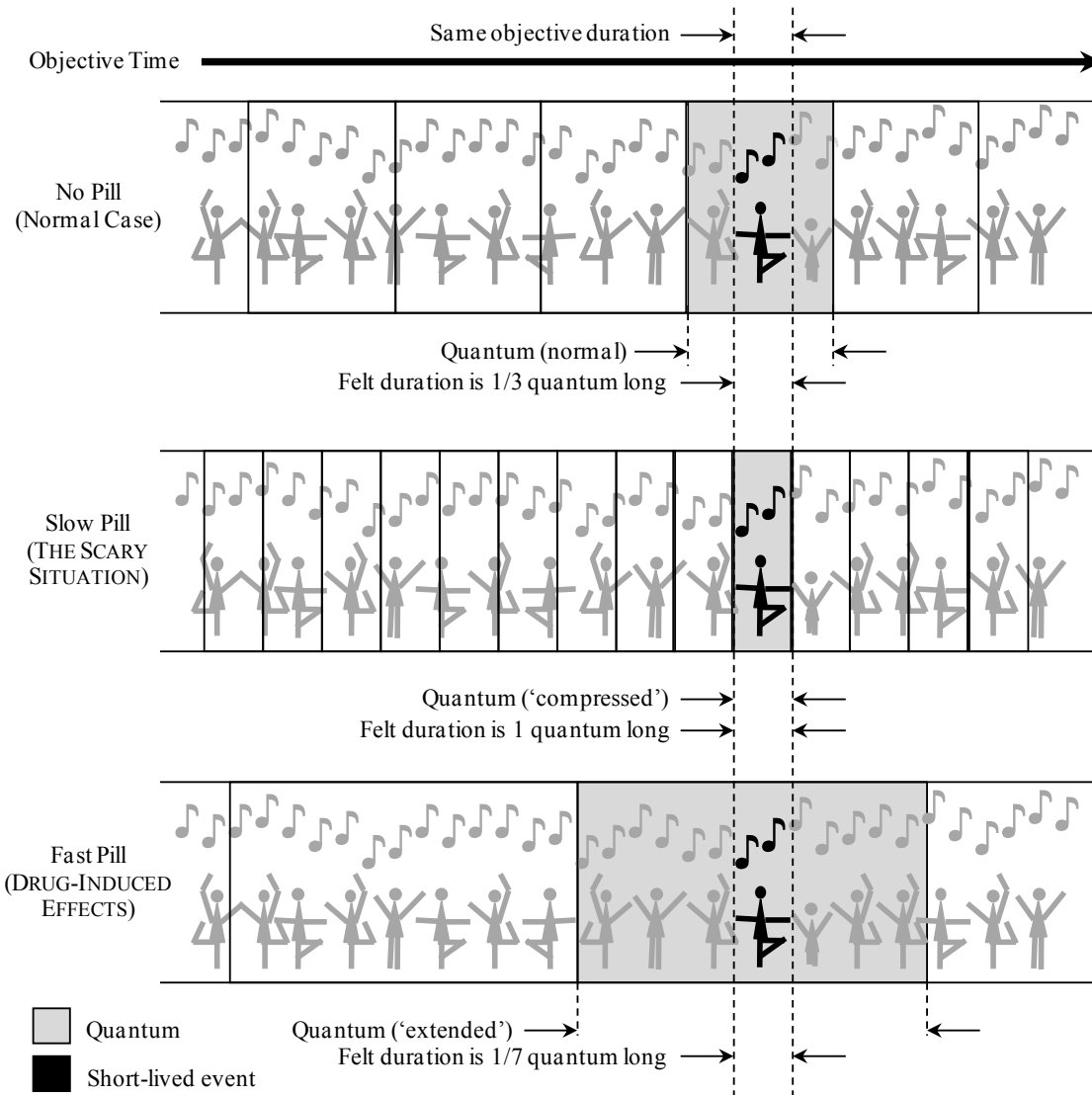


Figure 22. Objective durations for quanta in normal and illusory cases

As depicted in the figure, in all three cases the movement highlighted in black takes the same amount of objective time. The objective duration of the quantum in which this movement is taken in, however, differs in each case. In the normal case, the highlighted movement takes a third of its quantum and, hence, its felt duration is a third of a quantum-long. When the slow pill is taken, the same movement takes one quantum: its felt duration is a single quantum in length and thus three times longer than what it is in the normal case. When the fast pill is taken, the highlighted movement takes about one seventh of its quantum. Hence, its felt duration is roughly about half of what it is in the normal case and about seven times shorter than what it is when the slow pill is taken.

We can contrast figure 22 above with figure 23 below, where the same situations are depicted from the perspective of subjective time.

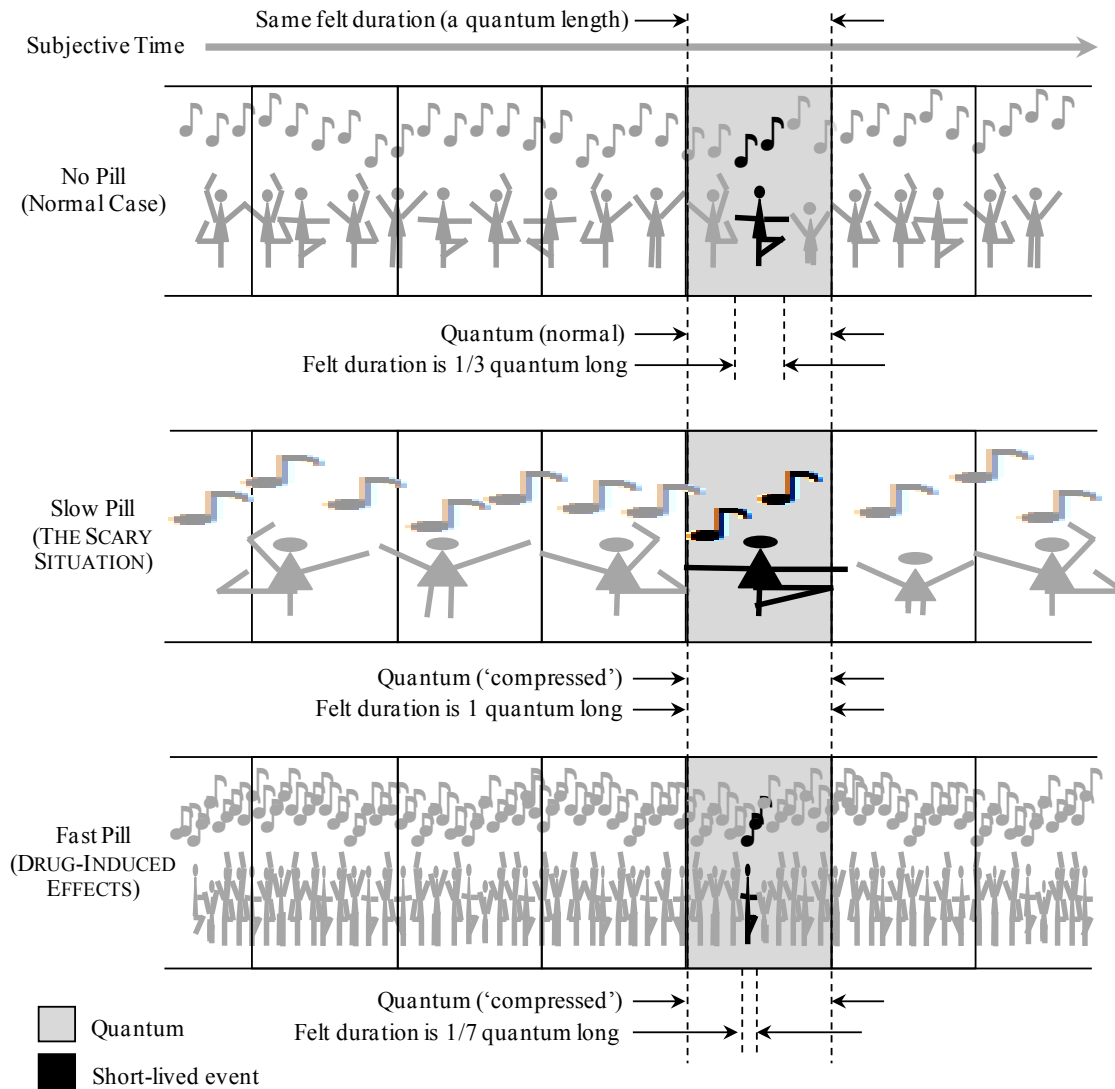


Figure 23. Felt durations for quanta in normal and some illusory cases

We can see from the figure that all the different quanta have the same *felt* duration: whatever is experienced as forming a tightly unified whole or quantum, regardless of what its objective duration is, is experienced as having the same duration. This is precisely what it means to take a quantum as the subjective unit of duration. The figure also makes it easy to see why,

when the quanta are ‘compressed’, their short-lived events are experienced as slowing down, whereas when they are ‘extended’ they are experienced as speeding up.

The hypothesis then is that drugs like haloperidol widen the temporal extent of the quanta—a fair amount of haloperidol might thus be what the fast pill consisted of. Having ‘extended’ quanta would thus be what explains the *speeding up of time* illusions in cases like DRUG-INDUCED EFFECTS. In an extremely frightening situation, the opposite effect occurs: the temporal extent of the quanta becomes narrower. ‘Compressed’ quanta would thus be what explains the *slowing down of time* illusion characteristic of cases like THE SCARY ACCIDENT.

Effects on Long-Lived Events

According to the theory put forward in the previous chapter, the felt duration of a long-lived event is the impression of the count of quanta formed in experiencing the event from beginning to end. When there is a decrease in the objective duration of each quantum—when the quanta are ‘compressed’—more quanta are needed to experience the same long-lived event. Because more quanta are experienced, other things remaining equal, an impression of a larger count is formed, or as I put it earlier, more quanta are ‘counted’. The effect of this is that the felt duration of the long-lived event is like the characteristic felt duration of an event with a much longer objective duration. In other words, we ‘overcount’ quanta.

Conversely, when the objective temporal size of the quanta increases—when there is an ‘extension’—fewer of them are involved in experiencing the same features of the whole long-lived event. Because there are fewer, other things remaining equal, an impression of a smaller count is formed: we ‘count’ fewer quanta. The effect of this is that the felt duration of the long-

lived event is like the characteristic felt duration of an event with a much shorter objective duration. That is, we ‘undercount’ quanta.

This dual effect of having ‘compressed’ or ‘extended’ quanta—one side of the effect being at the level of short-lived events and the other at the level of long-lived events—is what explains why in cases like *THE SCARY ACCIDENT* and *DRUG-INDUCED EFFECT* the felt durations of the short- and long-lived are congruent: they are either both longer or both shorter than the usual.

When the quanta are ‘compressed’ as in long-lived events like *THE SCARY ACCIDENT*, the felt duration of the short-lived events are longer: the short-lived events take up more of their corresponding ‘compressed’ quantum’s duration than of a normal quantum’s duration. The long-lived events are also experienced as taking longer: all else equal, more ‘compressed’ quanta are needed to take in the long-lived event than what would be needed if the quanta had their usual durations. This can be seen from figure 22: when the quanta are compressed—when the slow pill is taken—more quanta are needed to experience the same section of the dance.

Conversely, when quanta are ‘extended’ as in cases like *DRUG-INDUCED EFFECTS*, the felt duration of the short-lived events are shorter: the short-lived events takes up less of their corresponding ‘extended’ quantum’s duration than of a normal quantum’s duration. The long-lived events are also experienced as taking less time: all else equal, fewer ‘extended’ quanta are needed to take in the long-lived event than what would be needed if the quanta had their usual durations. This can also be seen from figure 22: when the quanta are ‘extended’—when the fast pill is taken—the same section of the dance is taken in with fewer quanta.

Because in cases like *THE SURPRISE PARTY* and *THE BORING MOVIE* the quanta are neither ‘compressed’ nor ‘extended’, there is an incongruity in the felt durations of the short- and

long-lived events. While the felt durations of the short-lived events remain the same—their short-lived events are not experienced as sped up or slowed down—the felt durations of the long-lived event are, respectively, shorter or longer than those of long-lived events of the same objective durations. The reason for this incongruity is then that in these cases the objective durations of the quanta are as they usually are.

In chapter one, we explained the duration illusions involving long-lived events in cases like THE SURPRISE PARTY and THE BORING MOVIE as illusions by ‘miscount’: by ‘undercounting’ of quanta in the former case and by ‘overcounting’ of quanta in the latter case. Let the illusions of felt duration over short-lived events that are due to changes in the size of the quanta be *illusions by ‘extension’ or ‘compression’*. As shown in figure 24, these two types of illusions can explain the effects of all four cases on the duration illusion chart.

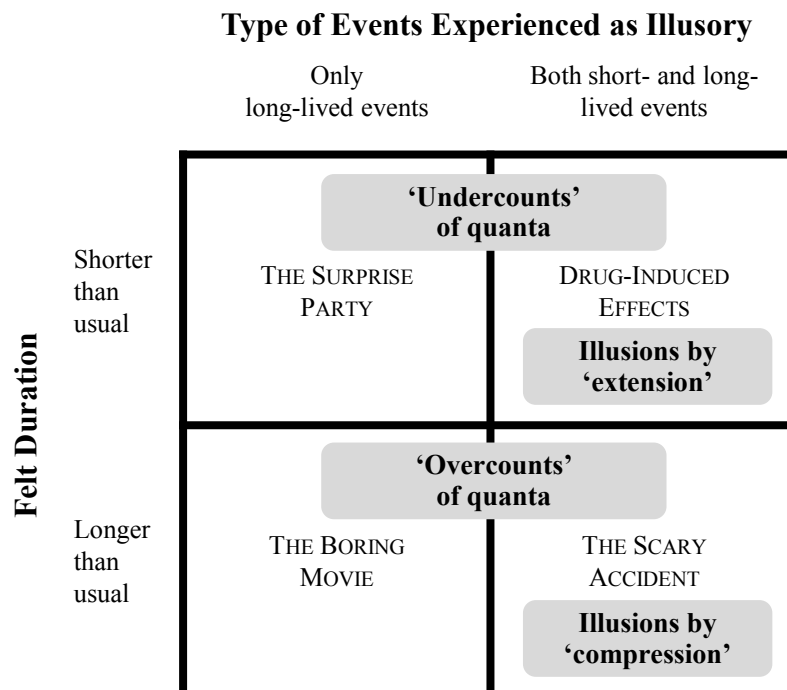


Figure 24. Duration illusions explained

As we can see from the chart, while all cases involve some type of illusion by ‘miscount’, only those in the right column also involve illusions by ‘extension’ or ‘compression’.

In this way, the theory developed can account for both veridical and illusory cases of felt duration.

Temporal Resolution for Short-Lived Events

You might think that the reason why the short-lived events during THE SCARY ACCIDENT or DRUG-INDUCED EFFECTS are experienced as slowed down or sped up is not that their durations relative to those of their surrounding quanta decrease or increase. Rather, what decreases or increases is how fine-grained the temporal phenomena taken in are. That is, you might think that a version of what was called in the previous chapter *the temporal resolution hypothesis* is what accounts for these cases.

As explained in the last chapter, according to the temporal resolution hypothesis, when we experience an event as lasting for more time than it really does, this happens because we experience more temporal phenomena: the temporal resolution of our senses increases. In this case, we would start experiencing changes that are otherwise too fine-grained to be perceived, such as small shifts in frequency that usually go unheard. The contrary occurs, according to this theory, when we experience an event as lasting less time than it does. In these cases, our temporal resolution would decrease: we would experience fewer temporal features. A rapidly flickering light that would normally be seen as flickering, for instance, would be seen as shining steadily.⁶⁹

⁶⁹ See Stetson et al. (2007).

The free fall experiment mentioned at the beginning of this chapter (Stetson et al., 2007) was designed to test this hypothesis. A device consisting of an electronic screen attached to the wrist of each participant flashed a number and its negative image on a led screen. As the authors explain, the device exploits an effect that takes place when two images are presented no more than roughly 80 ms apart from one another and at a flickering rate above a certain threshold. The effect is that the subject's visual system blends the two images into one simultaneous image.⁷⁰ You can see a depiction of this effect in figure 25 below.

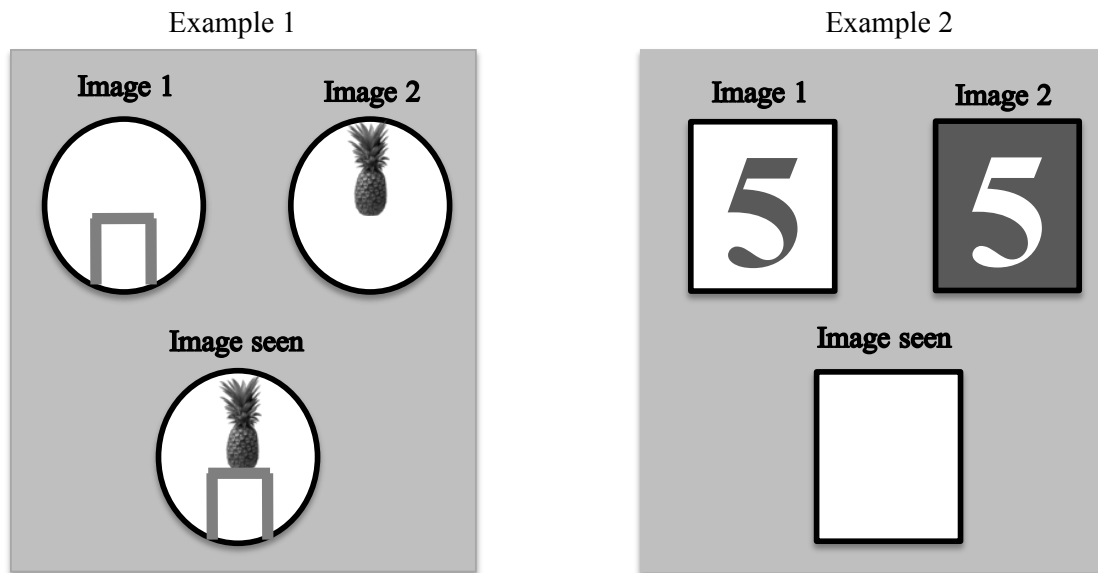


Figure 25. Example of the effect exploited by Stetson et al. (2007) in testing the temporal resolution hypothesis

⁷⁰ As explained in Stetson et al. (2007, p. 1), the experiment exploits the fact that there is a short integration window for visual images so that “[i]f two or more stimuli arrive within a single window of integration (usually ~80 msec), they are perceived as a single stimulus.” The authors reference this effect to Di Lollo (1977). In explaining this effect, they offer an example like the one given in figure 25.

The left side of the figure depicts this effect for a case in which the images shown (top left) are not negatives of one another. The image on the bottom left shows what the subject sees when the images at the top left are shown in alternation at a flickering rate above this threshold. On the right side of this figure you can see a depiction of the effect obtained when the alternating images (top right) are, as in the experiment, a number and its negative image alternating at a flickering rate slightly above the relevant threshold. As illustrated on the bottom right of the figure, at this flickering rate, the subjects are unable to see the number on the screen.

It was hypothesized by the experimenters that if an increase in the subject's temporal resolution was responsible for the *slowing down of time* illusion during the fall, the subject's temporal resolution should increase during the fall.⁷¹ Being able to discriminate more fine-grained temporal phenomena, the subjects should be able to see each of the two images separately if these were presented at a flickering rate just above the threshold. That is, if the temporal resolution hypothesis were true, the number should become visible to the subjects during the fall.

The results of the experiment showed that this was not so: the expected increase in the temporal resolution of the subjects was not found.⁷²

⁷¹ As explained by the authors of the experiment, it is reasonable to expect this increase partly because the “flicker fusion frequencies are not limited by the retina, since retinal ganglion cells have extremely high temporal resolution” (Stetson *et al.* 2007, p. 3). They also explain that from various other studies “it is clear that the limits of temporal resolution are central, not peripheral” (Stetson *et al.* 2007, p. 3).

⁷² See Stetson *et al.* (2007).

2.4 Conclusion

A Unified Account of Felt Duration

One of the underlying ideas of this discussion has been that we experience the duration of short- and long-lived events in different ways. As mentioned in chapter 1, this idea has been well-acknowledged within the psychological literature, where it has been widely held that the way in which we experience durations in the millisecond-to-second range is not the way in which we experience durations within the second-and-above range.⁷³ In spite of the fact that the duration of short- and long-lived events are experienced differently, as depicted in figure 26 below, these different ways of experiencing duration complement each other.

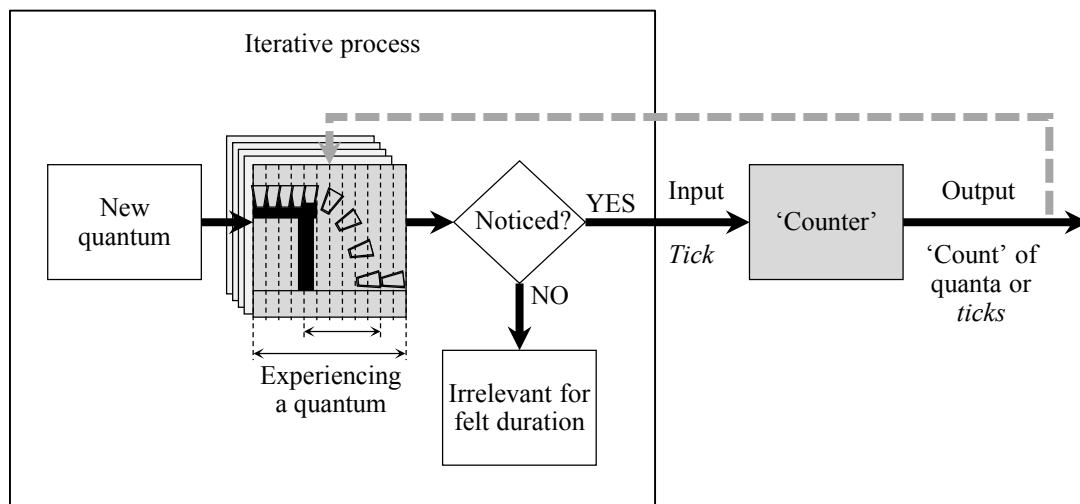


Figure 26. *A unified system of felt duration*

⁷³ For more on this, see footnotes 1 and 42.

According to the theory developed in chapter 1, the felt duration of a long-lived event is the impression formed of the count of quanta experienced during the long-lived event. According to the theory developed in this chapter, the felt duration of a short-lived event is how much of its corresponding quantum this event strikes us as taking up. A quantum, thus, serves to divide and unify both theories.

This division is required because events like parties and movies are too long-lived for us to experience them in the way in which, merely by casting a glance across the table, I might see the complete fall of the glass from the table to the ground or, if I glance at the computer screen, I might catch the whole flight of a bug across it. The unity is also needed because our experiences of duration of different short- and long-lived events can be compared with one another. Moreover, comparing them usually gives us a good sense of how their durations relate to one another.

While marking a natural division between two distinct ways of experiencing duration, a quantum nevertheless provides us with the common unit of a unified measuring system for felt duration.

Chapter 3:

Answers to Objections

In this last chapter, I consider and respond to five objections to the theory offered in the previous chapters.

OBJECTION ONE

According to the quantum theory of felt duration, my experience of a long-lived event is quantized; that is, broken up into distinct, temporally extended units. I do not, however, find my experience of long-lived events to be gappy. My experiences of the party, the dance show, or a cat wandering around the house for a couple of minutes unfold continuously.⁷⁴

RESPONSE

To experience a long-lived event in quanta is to experience it in distinct, individual, temporally extended units. The objection takes it that experiencing a long-lived event in this way must involve experiencing it as discontinuous, in the sense of experiencing it as having temporal gaps in which some intervening time passed between each quantum. As I explain below, this need not be so.

There are two ways in which the experience of a long-lived event could be quantized and continuous: (*i*) if adjacent quanta are experienced as sharing just one instant as their common

⁷⁴ I thank Anil Gupta for pressing me on this.

temporal limit; or (ii) if they are experienced as overlapping over a longer temporal stretch.

Figure 1 below depicts these two alternatives.

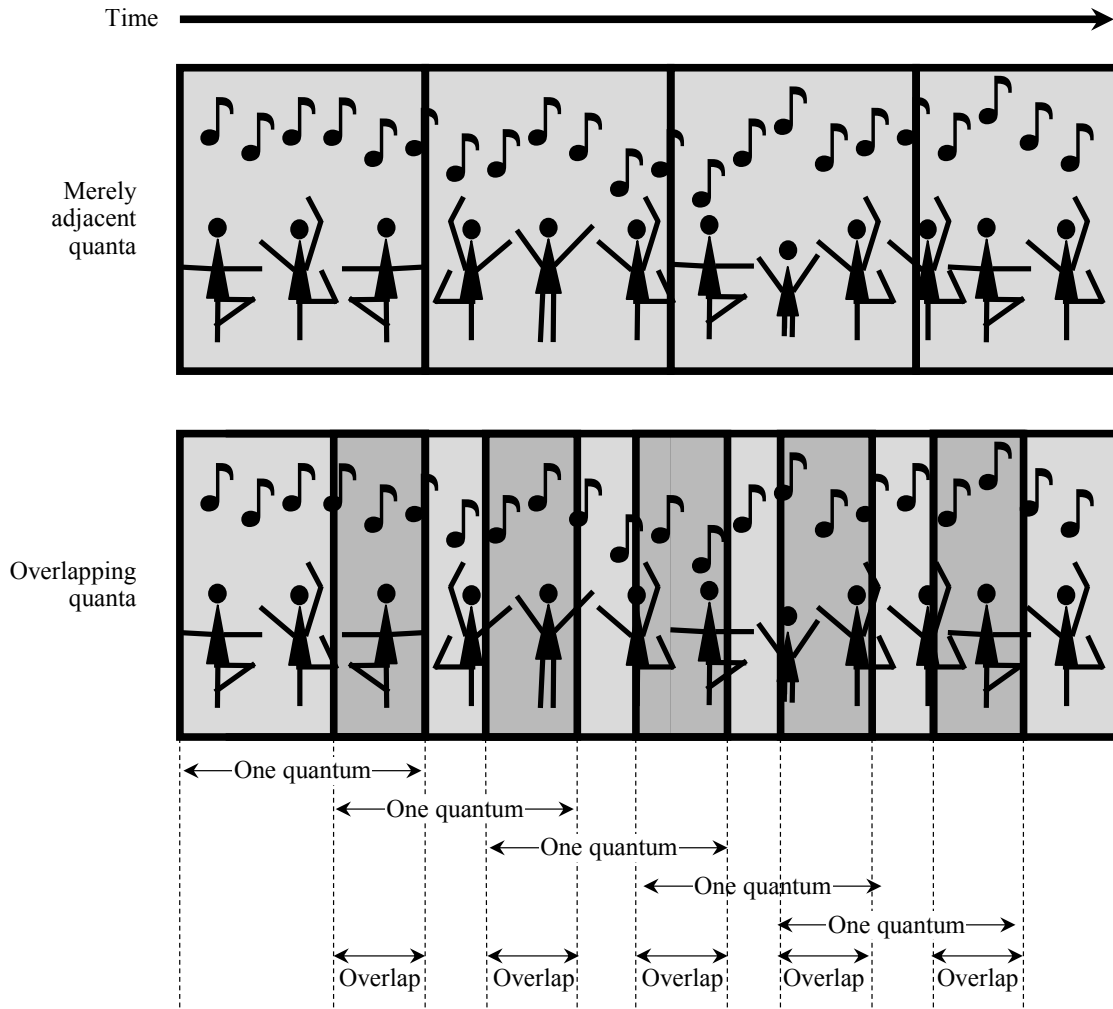


Figure 27. Two distinct ways of modeling the continuity of experience: merely adjacent or overlapping quanta

Let me further illustrate this by first considering the spatial analogue we have been using as a foil to build this theory—the case of seeing a section of the Berlin Wall—and then going back to the example of the dance show.

Suppose you are a few steps away from the Berlin Wall. This time you are not standing on the spot but walking along, looking at the graffiti. As you walk along, you take in various different looks of the wall. Figure 28 below offers a depiction of some of these looks.

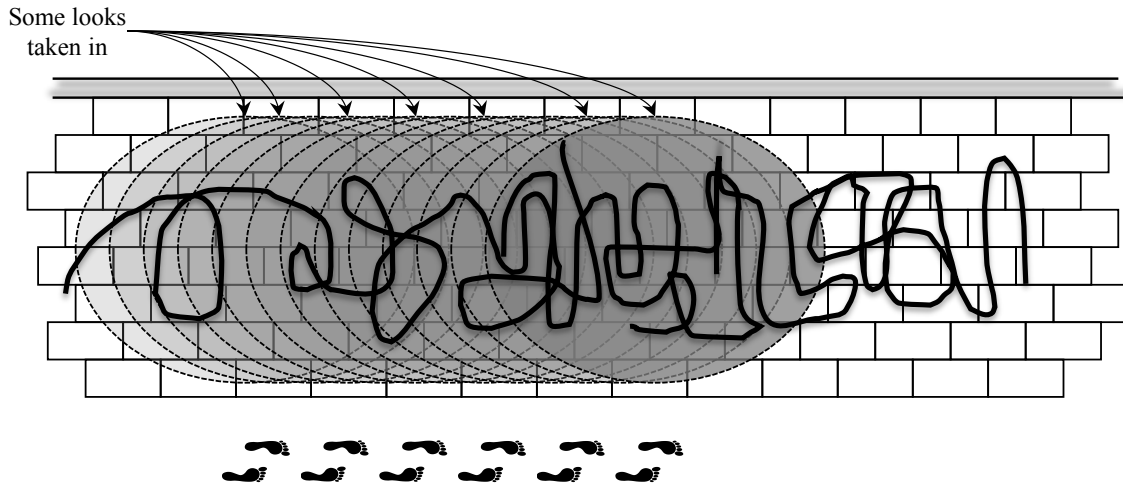


Figure 28. Various looks of The Berlin Wall taken in while walking along

As can be seen from the figure, the looks are overlapping: a spatially extended part of the wall is experienced as being part of consecutive looks (more than two in this case).

Consider any two consecutive looks. In taking these looks in, you do not experience the wall as having two different copies of the graffiti on the overlapped section, each on a different part of the wall. Instead, in taking in the later look, you experience the graffiti on the overlapped section *as being numerically identical to the graffiti taken in during the previous look*. Moreover, you do not experience the graffiti on the overlapped section as changing its spatial location even if, as you move along towards the right and take in the next look, the same graffiti is seen as being closer to the leftmost spatial limits of the present look than it did in the previous look. Rather, you experience the graffiti on the overlapped section as occupying a spatial location that

is *numerically identical to the one it was occupying when the graffiti was taken in in the previous look*. What changes is how much farther away this location is experienced as being from the one you experience yourself as occupying as you walk along the wall.

Since the same holds for any consecutive looks taken in during your walk, the following is true. Assuming that the spatial extension of each look is already seen as being continuous—and there is no reason to suppose this is not so—whatever section of the wall you see during your walk will also be experienced as being spatially continuous. Thus, while you see larger sections of the wall by taking in different, individual looks, as long as each of the subsequent looks are experienced as sharing some spatial part with the previous one, your experience of the section of the wall seen during your walk will also be seen as being spatially continuous.

If quanta are experienced as overlapping in an analogous way, then, by parity of reasoning, the stretch of time during which a long-lived event occurs will likewise be experienced *as temporally continuous*. To illustrate, consider the dance show and suppose that quanta indeed overlap. As time goes by, you take in subsequent, temporally overlapping quanta of the show, as depicted in figure 29 below.

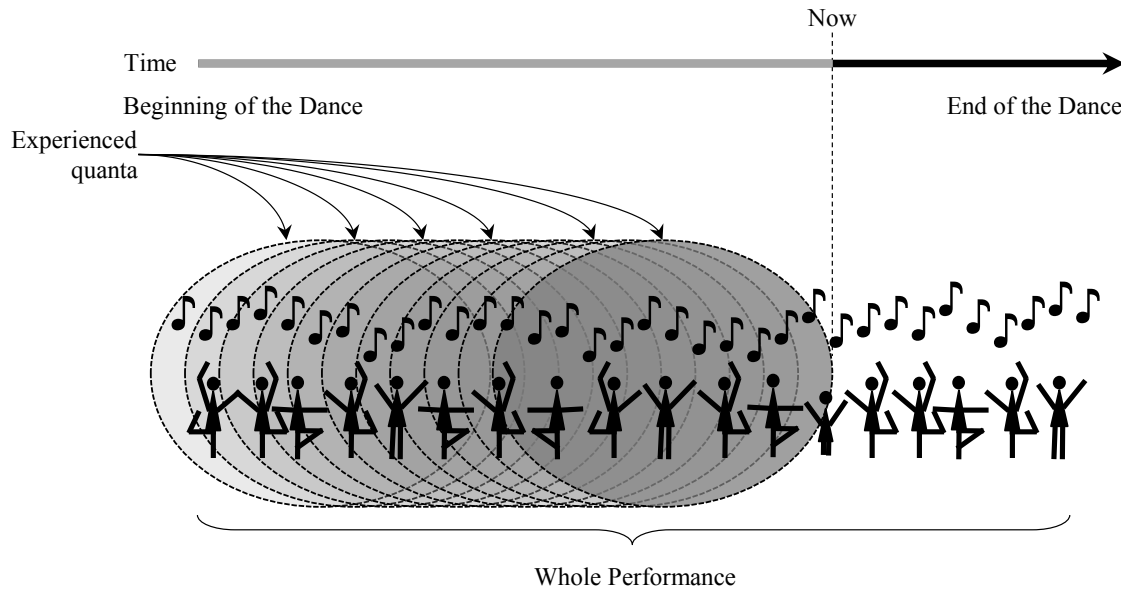


Figure 29. *Quanta experienced during a dance show*

If the situation is analogous to the spatial one just considered, in taking in subsequent quanta we would not expect to experience a repetition of the same movements and sounds—those corresponding to the overlapped temporal sections—as if the dancers and musicians incessantly repeated the latest bit. Instead, the movements and sounds on the overlapped section of the quantum currently being taken in would be experienced *as being numerically identical to those experienced in the preceding quantum*.

Moreover, even if the movements and sounds on the overlapped section change their temporal positions relative to the temporal limits of the different quanta in which they are taken in—the same movement is closer to the earliest temporal limits of a given quantum than to the temporal limits of the previous quantum—you would not experience these movements and sounds as changing their temporal locations. Rather, the movements on the overlapped section would be experienced as occupying temporal locations that *are numerically identical to the ones*

they occupied in the previous quantum. What the change in the temporal position of these movements relative to the temporal limits of each quantum amounts to is a change in how much farther away in time these movements are experienced as being from the temporal location you experience yourself as occupying as time passes and you take in more quanta.⁷⁵

In this way, while the whole dance show is taken in in different, individual quanta, as long as: (i) each of the subsequent quanta are experienced as sharing some temporal part with the previous one, and (ii) the temporal extension of each quantum is already experienced as being continuous—and, as with the spatial extent of looks, there is no reason to suppose that this is not so—you could in effect be experiencing the dance show as being temporally continuous.

Finally, note that the very same considerations could be offered if, instead of being experienced as overlapping over a temporally extended stretch, subsequent quanta were experienced as being merely temporally adjacent. That is, if subsequent quanta were experienced as sharing only the instant that is experienced as being at the latest and earliest temporal limits of each. But then, in either case, to experience a long-lived event in distinct, individual quanta would be to experience the long-lived event as temporally continuous.

⁷⁵ In this description, I have focused solely on the experience of what is known as B-properties of time—properties like occupying a temporal location that is earlier or later than another. Note that this description is consistent with the possibility of having further experiences as of A-properties—properties such as presentness, pastness, and futurity, which I do not here discuss.

OBJECTION TWO

Isn't what we experience at any given time an *instantaneous* slice of the situation encountered as opposed to a temporally extended slice or, as you call it, a quantum? In other words, wouldn't it be more intuitive to take an instantaneous slice of the situation encountered, and not a quantum, as what we take in through a single act of directed awareness, as the 'object' of our experiential consciousness? In what follows, I spell out this idea and offer two arguments in support of it. What is wrong with these?⁷⁶

(Note: The response to this question begins on page 104, after the two arguments in favor of this idea have been presented).

Consciousness of instantaneous slices

A principle that I shall call *consciousness of instantaneous slices* states that the object taken in through an act of experiential consciousness is an instantaneous slice of the object, event or situation encountered. The main idea behind this principle is that all we ever experience is what happens at an instant. Thus, if I see a soccer player shooting the ball into the goal, I see this partly in virtue of seeing instantaneous slices of this shooting. More generally, one is

⁷⁶ An earlier version of my discussion of this objection was presented at the Northwest Workshop on Time and Rationality, at the Princeton Luce Seminar on Philosophy and Psychology, and at Princeton Philosophical Society. Thanks to the audiences of these events for their helpful comments and suggestions. Thanks also to Lara Buchak, Tom Dougherty, and Meghan Sullivan for inviting me to the Northwest Workshop on Time and Rationality. In thinking about this, I also benefited from reading the sections of Lee (2009) and Dainton (2006) where this topic is discussed. Chisholm's (1981) paper on Brentano's account of time consciousness was also helpful.

experientially conscious of an object or event that spans over some time partly in virtue of being experientially conscious of instantaneous slices of this object or event.

It is worth considering why the following, stronger formulation of the principle would be problematic: experiencing an object or event spanning over some time consists *solely* of experiencing instantaneous slices of it. Suppose that, in order to practice, you line up three soccer balls close to the goal and then shoot them rapidly one after the other. If I see you doing this, what I have seen is a succession of shots: I saw the third ball as having being shot after the second one and the second one as having been shot after the first one. Contrast this with the case in which on Monday I see you shooting a soccer ball into the goal, on Tuesday I see you shooting another ball into the goal, and on Wednesday I see you shooting a third ball into the goal. In this case, it is true that there has been a succession of shots on goal. It is also true that I have seen parts of this succession. Moreover, if I reflect on this, I may *realize* that what I have seen forms a succession. Nevertheless, I have not *seen* a succession.⁷⁷

The problem with the stronger claim is that if seeing a succession of shootings solely consisted in seeing instantaneous slices of it, one would be forced to conclude that in both cases I saw a succession. To avoid this, what is claimed instead is that seeing the succession involves more than just seeing instantaneous slices of it. Some theories, for example, add that seeing the succession consists in seeing an instantaneous slice of it while having memories of the previously seen instantaneous slices of it. According to other theories, what is added is a higher-

⁷⁷ Cf. Chisholm's (1981). My understanding and discussion of this problem draws on Chisholm's helpful explanation of his understanding of Brentano's account of time consciousness.

order consciousness of the seeing of the current instantaneous slice together with the seeings of previous instantaneous slices of the succession.⁷⁸

Since I will be constantly referring to this principle, let me state it as follows.

CONSCIOUSNESS OF INSTANTANEOUS SLICES The object taken in through an act
of experiential consciousness is
instantaneous.

I will now consider two arguments in support of this principle. Though these are meant to generalize to the objects of seeings, hearings, touchings, smellings, tastings and, more generally, of a single act of directed awareness or—as I have also called it—experiential consciousness, I focus mainly on visual experience because this is where the principle has been thought to enjoy the most intuitive support.

Two Arguments

ARGUMENT 1: THE PHOTO ANALOGY

The idea is that the principle captures what we intuitively take our experiential consciousness of the objects and events around us to be like.

Consider seeing a soccer match. It is intuitively attractive to think of this experience in terms of the following analogy. Just as in the movies the projection of a longer scene partly consists in various projections of photo-like scenes, seeing the soccer match partly consists in

⁷⁸ According to some versions of both of these theories, expectations are also involved. In the case of the first type of theories, they accompany memories. In the case of the second type of theories, they are included in the object of the second order act of consciousness.

rapidly seeing many photo-like scenes of the match, where all of these scenes are large enough to cover one's entire visual field.⁷⁹

From this, and from the further assumption that seeing these photo-like scenes is what seeing instantaneous slices of the match is like, it is concluded that our intuitions about what it is like to see the soccer match support the idea that seeing the match consists in seeing many of its instantaneous slices. In this way, the principle of consciousness of instantaneous slices is thought to enjoy intuitive support.

ARGUMENT 2: TEMPORALITY

While seeing the cup on top of my desk, I do not take my seeing to occur at a time in the past or in the future: I take it to occur at the present time. Contrast this with the case in which, while looking for my cup, I *remember* seeing it lying on the desk the day before. In this case, I take the seeing of the cup on top of the desk that I now remember as having happened at some time in the past. More generally, while being conscious of something, I take my consciousness of it to occur at the present time. Let this intuition be called *presentness*.

Also, in seeing the cup on top of my desk, I do not take what I see as taking place some days before or after my seeing of it. Rather, it strikes me as being there while I see it. This is why, while seeing the cup on top of the desk, I reach to get a hold of it. The same goes for other types of consciousnesses. I take the smoke I smell to be present at the time I smell it and the bitterness I taste to be present at the time I sip the lemon juice. That is, we intuitively take the

⁷⁹ Perhaps these photos should be 3D and look as if they bent towards their periphery.

object we are presently conscious of and the consciousness of it as being simultaneous. Call this intuition *simultaneity*.

Finally, we intuitively think of the present as being instantaneous. Let *instantaneity* be the name of this intuition.

Taken in conjunction, presentness, simultaneity, and instantaneity support the principle of consciousness of instantaneous slices. For if we intuitively take it that the present is instantaneous and that while seeing something that seeing occurs at the present, then we must also take the seeing as instantaneous. Also, if we intuitively take the scene we see and the seeing of it to occur simultaneously, then we must also be taking this scene as instantaneous.

RESPONSE

In what follows, I argue that none of these arguments provide good reason to accept this principle.

AGAINST THE PHOTO ANALOGY

According to this argument, we intuitively take seeing the soccer match to partly consist in seeing many large photo-like images of the match, ones covering all of our visual field. Not any photo, however, will do. An artistic photo that looks mainly blurred or one taken from the window of a rapidly moving train, for instance, won't. We are supposed to consider the kind of photos one would normally find in, for example, a family photo album. In the case of the soccer match, this is the type of photo that a reporter might shoot for a sports magazine. What characterizes these photos is that seeing them is like seeing a static scene.

Consider, for instance, two such photos: a photo of a team taken before the match begins and one of a player committing a foul. It is clear why seeing the team photo is like seeing a static scene: the players deliberately stand still during the shooting. The photo of the player committing a foul is trickier only because seeing it invites us to consider the larger situation of which the photographed scene is a part, which usually exhibits many changes. In this case, it involves another player being taken down, the ball crossing the field, someone at the other end receiving the pass, and so forth. Focus, however, only on the photographed scene. While it is also true of this scene that it is not static—the player was indeed moving during the small interval of time during which the lens of the camera received light from the scene—if the photo is taken at a shutter speed that is fast enough compared to the speed at which the player is moving, his moving will have a negligible effect on the photo. Hence, since the changes neither of the larger scene nor of the photographed scene have effects on the resulting photo, seeing it, just as seeing the team photo, is like seeing a static scene.

This allows us to further clarify the proposal being offered: seeing a long-lived event involves seeing many static scenes of this event. Seeing a soccer match, for instance, involves seeing many static scenes, scenes that look very much like those on the next day's sports magazine.

A first problem with the argument offered is that even if our intuitions were to support this picture, they would not thereby support the principle of consciousness of instantaneous slices. This is so because the picture offered lends equal support to views that endorse the principle and to those that endorse its negation. The reason for this is that the photo analogy trades on what it is like to see a static scene to explicate what it is like to see an instantaneous

scene. And when we see a scene as static we see it as lacking change⁸⁰ but not necessarily as lacking duration. As a result, seeing a scene as static is compatible with seeing it as having some duration.

To illustrate, imagine you enter a theater and see what looks like a soccer match. The theatrical scene you see, however, is peculiar in a way that soccer matches are not: no one is moving. In an impressive balancing act, the actors stand in what looks like sliding, running, and kicking positions, but none of them moves. Still, what you see is very much like what you would see if a huge photo of the match occupied all of your visual field. By staring at the theatrical scene for a couple of seconds you would thereby see a scene that is both static *and* has some duration. But then, from the fact that you are seeing a static scene you cannot thereby conclude that what you are seeing is an instantaneous slice of the match.

Note further that adding the constraint that seeing an instantaneous slice is like seeing a scene as static *and as having no duration* would result in the argument begging the question. For in order to show that the principle of consciousness of instantaneous slices has intuitive support it would be assuming that seeing the match partly consists in seeing many scenes of the match that are static and *instantaneous*. But then the photo analogy would be unable to show that the object taken in through an act of experiential consciousness is instantaneous.

Furthermore, to claim that the principle itself enjoys intuitive support would be to claim that we simply take ourselves to be experiencing instantaneous slices of the events we encounter.

⁸⁰ There are, however, motion illusions—like the waterfall illusion—that involve seeing a scene both as static and as moving.

But what exactly is it like to see an instantaneous slice? To try to get a handle on what this would be like, consider the following analogy with space.

Try to imagine what it would be like to be visually conscious of only a vertical line. The first thing that comes to mind is something like a very thin line lying between two dark surfaces. This, however, is not really what being visually conscious of just a vertical line is like, because the way in which the dark surfaces look is also part of the image. The same problem arises if we consider what it would be like to see just one spatial point: the best we can do is to imagine seeing a very small dot surrounded by a contrasting area.

The difficulty of doing this clashes with the readiness with which we imagine spatially extended things, like a soccer field, the sky above the stadium, or the scene of the match in front of your eyes. This suggests that we never really have visual experiences of just a line or a space point but only of spatially extended scenes.

Something analogous seems to hold in the case of time. The difficulty in coming up with what it is like to see just an instantaneous scene contrasts with the readiness with which images of short-lived scenes come to mind. Think of what it is like to see the ball flying across the field for a couple of seconds, or the goalkeeper jumping and falling on his knees, or the stadium flags waving over a clear sky. This again suggests that we never really see just an instantaneous scene. Instead, every time we see a scene, the scene is already seen as spanning over an interval of time.

It follows that even if our intuitions were to support views according to which the objects of our visual conscious acts are scenes that look *static*, this would not thereby support the claim that these scenes are *instantaneous* more than it supports the claim that these scenes have some duration.

A second problem with the photo analogy is that it is not true that we find the picture offered an intuitively appealing description of our experience of seeing events such as the soccer match. Rather, what our intuitions support are the following two ideas.

Firstly, as has already been mentioned, it is true that we seem to see longer-lived events partly in virtue of seeing shorter-lived slices of these. Consider again my seeing the soccer match. I see the match partly by seeing the defender sliding to kick the ball away from his opponent, the goalkeeper jumping forward to catch the ball, the referee raising his hand to call offsidess, and many other shorter-lived slices like these. I do not, for instance, think that by simply glancing over the soccer field I can see the entire 90-minutes match. I must sit patiently and take the match bit by bit.

We also have the intuition that *some* of these short-lived slices look static. By staring at the empty soccer field before the match starts or at the players as they stand resting before the second half begins, I might see short-lived slices of the match that look static. What is not intuitive, however, is that seeing the soccer match partly consists in seeing short-lived slices of it *all of which look static*. Having this intuition would amount to having the intuition that seeing the soccer match is like seeing a slideshow presentation of magazine-like pictures of the match.⁸¹ But seeing the match is not like seeing the slideshow presentation! To further illustrate this, consider the following case.

You see a glass about to fall off your desk but not yet moving. Instead of reaching to grab it, you zone out for some fraction of a second—you have been working for too long—and then see the broken glass on the floor. Assuming all else is phenomenologically equal (suppose you

⁸¹ You would also have to ignore seeing the changing of the slides.

were wearing earplugs and didn't hear the sound of the glass crashing on the floor), seeing this involves seeing a static scene of the glass on top of your desk followed by seeing a static image of the glass broken on the floor (also, assume that the glass is no longer moving when you see it on the floor). This is how seeing the slideshow presentation would be like. Contrast this with the case in which you do not zone out while the glass falls. While in the first case you simply *realized* that the glass had fallen—perhaps while seeing the glass on the floor you remembered the visual image of the glass on top of the desk a few seconds before and inferred from this that the glass must have fallen—in the second case you also saw the fall. But to see the glass falling is to see a scene that is not static!

As mentioned above, one might attempt to explain this difference while maintaining that seeing the change in positions of the glass as it falls consists in seeing static scenes by, for example, appealing to memory or a higher-order consciousness. Seeing the glass change positions as it falls, thus, would involve seeing a static scene of the glass in one position accompanied either by memories of previous static scenes of the glass at other positions or by a consciousness of various past seeings of these static scenes. None of these experiences, however, accords with what we intuitively take it to be like to see the fall of the glass. Note that the point is not that these proposals are impossible to defend, but that they are not supported by what we intuitively take our experiences to be like.

And, as we have seen throughout the previous chapters, perceiving short-lived changes like those involved in seeing the fall of the glass is something we do all the time. Take again a coin out of your pocket, hold it in your hand and, while looking at it, let it fall down. You see the coin's falling and see it as lasting for a little bit of time. The phenomenon is also found in the rest of our sensory modalities. Not only do we see the *movement* of a coin as it falls from your

pocket, but we also hear the short *dong* of a doorbell as coming after the longer *ding*, feel the *movement* of a finger as it slides across one's arm, taste the *change* in flavor of the mint-coated strawberry gum, smell the *increase* of vanilla aroma in the room as the perfume is sprayed, and even perceive a sudden change in mood after receiving good news.

Our intuitions, then, do not support the idea that all we see are static images of the objects around us, as the picture offered by the photo analogy would have it. Instead, our intuitions support the negation of this claim: they support a view according to which we constantly see scenes as exhibiting temporal features such as brief movements, objects changing properties, events succeeding one another, and the like.

Since the type of temporal features that we seem to experience occur over brief but extended periods of time, in experiencing these temporal features we must be experiencing slices of events that span for more than an instant.⁸² But then, not only do our intuitions conflict with the picture offered by the photo analogy, but it is also true that they support the claim that short-lived slices are often the objects of our perceptual consciousness. Thus, our intuitions support the negation of the principle of consciousness of instantaneous slices.

So far, I have argued that the picture offered by the photo analogy does not support views that endorse the principle of consciousness of instantaneous slices more than it supports views

⁸² This relies on the assumption that either there are no instantaneous changes or if there are and we can be perceptually conscious of instantaneous slices, then we cannot be perceptually conscious of the changes within these. It also seems plausible to make the same assumption for the case of changes that occur during extremely short but temporally extended slices: if we can be perceptually conscious of these instantaneous slices, we cannot be conscious of them as changing. For example, even if I could see a slice that lasts for a nanosecond, I cannot also see the movement of the electrons during it.

that endorse its negation. I have also argued that the picture according to which being conscious of longer-lived events consists partly in being conscious of scenes *all* of which look static does not enjoy intuitive support. Finally, I suggested that what seems to enjoy intuitive support is the picture according to which we experience scenes exhibiting temporal features and that this, in turn, seems to require us to be experientially conscious of slices that span over more than an instant. Thus, it is the negation of the principle of instantaneous consciousness that seems to enjoy intuitive support.

AGAINST TEMPORALITY

According to this argument, the intuitions we called presentness, simultaneity, and instantaneity, taken together, support the principle of consciousness of instantaneous slices. Basic physical and physiological facts, however, stand as a reason for rejecting simultaneity. Without simultaneity, our intuitions no longer support the principle.

To see a scene, the light reflected from it needs to reach my retinas. Since it takes some time for light to traverse the distance between the scene and my eyes, if I become visually conscious of it at a time t , then the scene must have occurred at a time earlier than t . If the scene is too far away from me, like when what I see is a starry sky, then the scene must have occurred at a much earlier time. So even if upon seeing a starry sky I have the strong intuition that what I see is how the sky is at the time I see it—that is, at the present time—basic physical and physiological facts give me reason to correct myself and give up this intuition. But then, though this may be a useful intuition to have, it is false that my seeing of a scene and the scene I see occur simultaneously; what I see is not how the scene looks at the time I am conscious of it but how it looked at an earlier time.

Rejecting this intuition is enough to undermine the support for consciousness of instantaneous slices given by this argument. Without it, we no longer have reason for thinking that the slice seen is simultaneous with the seeing of it. But then we do not have reason to think of it as happening at the present, and hence no reason to think of it as instantaneous. After all, at the time we see it, at least part of it is already in the past. Hence, even if the present is instantaneous, this does not give us reason for thinking that the temporal slices of what we see are instantaneous as well.

If all this is correct, then the reasons offered are no good reasons for holding on to views that endorse the principle of consciousness of instantaneous slices. Moreover, we have good reasons for holding on to views that deny this principle. Let me end by sketching a view that denies this principle and that makes sense of all the intuitions so far discussed and by noting one of its consequences.

The emerging picture is this. First, individual, short-lived slices are the objects taken in by an act of experiential consciousness. Second, it is partly in virtue of being experientially conscious of many of these slices that we become experientially conscious of longer-lived objects and events. Third, by taking in one of these short-lived slices, we can experience what occurs during various shorter slices of it, even if these shorter slices cannot individually be the objects of our consciousness. According to this view, thus, the objects of our experiential consciousness can already be experienced as having durations.⁸³

A consequence of this view is that the objects and events that can be perceived in a short-lived slice can already be perceived as persisting. An advantage of this view over one that

⁸³ For a defense of a view like this, see Phillips (2009).

defends the principle of instantaneous slices is that explaining our consciousness of the identity over short periods of time of such objects and events would not be more problematic than explaining our consciousness of their colors, pitches, flavors, or shapes. That is, we would no longer need to explain how we become conscious of objects and events as being identical over small periods of time for the simple reason that we are never in the position of being conscious of instantaneous slices of these that we then need to stitch into a persisting object. Short-lived objects and events can simply disclose their identities over time in very much the same way in which they disclose any of the other features we are experientially conscious of. When perceived, a short-lived object could simply exhibit its persistence.⁸⁴

OBJECTION THREE

Instead of quanta—that is, the longest-lived slice of the situation experienced as unified—why not take the *shortest*-lived slice of the situation experienced as the unit of felt duration? Note that this proposal is compatible with accepting that this unit is neither instantaneous nor experienced as instantaneous. Wouldn't this deliver a simpler theory?⁸⁵

RESPONSE

Taking quanta to be the unit of felt duration has the following advantages over taking the shortest-lived slice of the situation experienced to be this unit. Recall our duration illusion chart, shown again below.

⁸⁴ For another discussion against views that hold on to the principle of instantaneous slices, see Lee (2009).

⁸⁵ Thanks to Benjamin Jantzen and Japa Pallikkathayil for pressing on this.

		Type of Events Experienced as Illusory	
		Only long-lived events	Both short- and long- lived events
Felt Duration	Shorter than usual	THE SURPRISE PARTY	DRUG-INDUCED EFFECTS
	Longer than usual	THE BORING MOVIE	THE SCARY ACCIDENT

Figure 16. Classification of duration illusions

In accounting for the duration illusions in the left column, the quantum theory exploited the fact that quanta could be ‘miscounted’ while maintaining their objective durations. The effect of this is to confine the illusion to long-lived events; since a short-lived event is shorter-lived than a quantum, ‘miscounting’ quanta would not affect their felt durations. If we took the unit of felt duration be the shortest-lived slice that is experienced, however, this would no longer be so. Since what we have called short- and long-lived events would both be longer-lived than the unit of felt duration, ‘miscounts’ of these units would have to affect the felt duration of both short- and long-lived events. ‘Miscounts’ would therefore be unable to explain the cases in the left column of the chart.

In accounting for the duration illusions concerning short-lived events involved in the cases in the right column of the chart in figure 16, the theory exploited the fact that quanta could

have longer or shorter objective durations while still being experienced as taking the same amount of time. These were called *illusions by 'extensions' and 'compressions'*. If the unit of felt duration was the shortest-lived slice experienced, however, the results of the free fall experiment considered in the previous chapter would count against this explanation. For if this were so, in order for the short-lived events in a case like THE SCARY ACCIDENT to be experienced as slowing down, they would have to be experienced by taking in more of these units than usual. But then, the units would have to be shorter-lived than the usual. This would thus require the subject to be able to take in more fine-grained temporal phenomena than what she usually experiences. That is, this theory would require the subject's temporal resolution to increase during the scary situation. And this is precisely what the free fall experiment showed was not the case. That is, the explanation would be committed to some version of the temporal resolution hypothesis, which we are taking the free fall experiment to have falsified.

Because quanta are not the shortest-lived slices experienced, having quanta of shorter objective durations does not have as a consequence an increase in the subject's temporal resolution. Reducing my visual field need not imply that my spatial resolution increases (though this could also be true) but only that the look I take in covers a smaller spatial stretch. Likewise, having quanta of shorter objective durations does not imply an increase in temporal resolution; all it implies is that the slice of the situation that is experienced as a tightly unified whole has a shorter duration. As was explained in the previous chapter, if quanta get 'compressed', instead of being able to take in a whole pirouette in one quantum one might take in just one third of the pirouette. And this in no way requires one to also take in this bit of the dancer's movement with a higher temporal resolution.

Finally, as explained in chapter 1, quanta have a distinctive phenomenology that makes them suitable for being ‘counted’ and ‘measured’ and, hence, suitable for being that in terms of which the felt durations of other events are given. It is unclear to me what the distinctive phenomenology of these other units might be which, independent from that of quanta, makes them suitable for being counted and measured.

If the phenomenological account of these units relies on that of quanta (if for example, these units were taken to be experienced as the shortest-lived slices of the situation which, together with other such units are experienced as a tightly unified whole), then the explanatory advantages of taking quanta as the unit of felt duration pointed out above would count in favor of taking quanta as the unit of felt duration.

None of this is meant to show that building a theory out of these units is impossible. It is rather meant as an explanation of why, *prima facie*, modeling felt duration by taking quanta as the unit of measurement seems to me more appealing. Someone might try to offer an alternative account based on these other units.

OBJECTION FOUR

Could the model be used to explain the ‘speeding up of time’ phenomenon observed with aging?

RESPONSE

A Speculation about Aging and the Experience of Time

This is one more phenomenon about which I would like to say something in a more preliminary way. It has been widely held that during childhood, days, months, and years seem to

last for much longer than the way we experience them later in life.⁸⁶ Because it is not just this particular party or that particular soccer match that seems to go slower or faster, I will say that the phenomenon is *non-transient*. Instead, this has been thought of as being a progressive phenomenon that begins early on: as we become older, time seems to pass faster.⁸⁷ What this means is that on her 45th birthday, someone that will live for 90 years would already be well past the first half of her subjective life.

While this phenomenon affects how the duration of long-lived events are experienced, it is less clear that it also affects our experiences of the durations of short-lived events. For a child, the bouncing of a ball or the falling of a coin from her pocket does not seem to happen in slow

⁸⁶ For instance, in a study involving almost 300 subjects between 62 and 94 years old (with a mean at 75 years), Baum et al. (1984) reported that “[f]or the majority of elderly in this study (60.1 percent) time passed quickly. Only 22.7 percent experienced time as moving about the same as it had always moved, and 13.3 percent felt as though time were moving slower than previously experienced.” Baum et al. (1984, p. 56). As noted by Block et al. (1998) it was James (1890, p. 284) who “claimed that “the same space of time seems shorter as we grow older,” but he qualified this by saying “that is, *the days, the months and the years* do so; whether the hours do so is doubtful, and the minutes and seconds to all appearances remain the same”” (Block et al. (1998), p. 585, my emphasis).

⁸⁷ As pointed out in Friedman and Janssen (2010), there are a number of studies (Gallant et al. (1991); Joubert (1983); Joubert (1984); Joubert (1990); Lemlich (1975); Tuckman (1965); Walker (1977); Wittmann and Lhenhoff (2005)) in which subjects were asked to compare how fast time seems to be passing at their current age with how it seemed to pass at earlier ages, and from which one can conclude that older adults think that time passes faster during adulthood. Moreover, young adults *also* think that time seems to be passing more quickly now than when they were younger (Cf. Friedman and Janssen (2010, 132)). This suggests that the phenomenon begins at an early age and progresses as we become older. Note, however, that the results in these studies suggest that “[o]nly when reflecting on *very long intervals of time* [of the order of ten years] does the speed of time’s passage seem to increase during adulthood” (Friedman and Janssen 2010, p. 139, my emphasis).

motion, nor do the words uttered by her parents seem to go really slowly. Rather, it is the whole day what seems to be so long, a school year an eternity. Likewise, it is not as if during adulthood the falling of the glass from the table to the floor appears to happen especially quickly. Rather, it is years, months, weeks, or days that seems to be flying by. Thus, if we were to include these cases in our earlier illusion chart, we would classify them as shown in figure 30 below.

		Type of Events Experienced as Illusory	
		Only long-lived events	Both short- and long-lived events
Felt Duration	Shorter than usual	THE SURPRISE PARTY	DRUG-INDUCED EFFECTS
	Longer than usual	THE BORING MOVIE	THE SCARY ACCIDENT
		Transient	Non-transient

Figure 30. Expanded classification of duration illusions

As can be seen from this chart, the duration experiences characteristic of childhood and late adulthood would be, respectively, the non-transient analogues of THE BORING MOVIE and THE SURPRISE PARTY. Because of this, it is appealing to try out the same explanation offered in these transient cases to capture what is going on in the non-transient ones. This would involve

explaining the changes in the experiences of the duration of long-lived events between childhood and late adulthood as the result of a chronic change in attention that comes with the process of aging. This would, in turn, give rise to more ‘miscounts’ of the number of quanta involved in experiencing long-lived events as we age.

Changes in Attention

One way in which these ‘miscounts’ could be produced would be if our overall level of attention declined with age. This hypothesis has been supported by studies showing that young adults asked to perform different, simultaneous tasks and divide their attention between them showed a reduction of performance that matched that of older people who perform only one of these tasks and, thus, were able to allocate all of their attention to it.⁸⁸ Let us assume that the number of quanta that it takes a younger and an older subject to experience an event is the same. It follows that because the older subject has fewer attentional resources, she will notice fewer quanta than the younger. But then the older subject would form an impression of a smaller number of quanta; that is, the older subject would ‘count’ fewer. The older subject would thus experience the event as lasting for less time than the time the younger subject would experience it as lasting.

Some studies, however, have challenged the idea that our level of attention declines as we age. Instead, it has been proposed that there is a change in how older people *allocate* the same

⁸⁸ See Lustig (2003, section 10.1.2). This paper offers as helpful summary and discussion of these issues. As mentioned in this paper, the studies from Craik and Hay (1999) and Anderson et al. (2000) lend some support to the idea that our level of attention decreases with age.

attentional resources.⁸⁹ The idea is that the decline in the motor and perceptual abilities of older people requires them to dedicate more attention to the performance of ordinary activities that younger people do almost automatically.⁹⁰ Since for older people more attention would be devoted to performing these simple tasks, less attention would be devoted to keeping track of time. In terms of our model, this would mean that as we age, we would pay less attention to the passing quanta and their ‘counts’, which would then result in noticing less quanta and, therefore, in ‘undercounting’ them (as explained in the section on illusions by ‘miscount’ in chapter 1). It would be as if older people were permanently in a situation like THE SURPRISE PARTY. Their attention is not captured by the exciting events of the party that they are living through, but by

⁸⁹ See Lustig (2003). As Lustig explains, the meta-study in Block et al. (1998) and the study of Craik and Hay (1999), taken together, support the idea that what could explain the differences between older and younger duration estimates is a difference in how they allocate their attentional resources (see also Block et al. (1998)). As Lustig explains, the study in Block et al. (1998) analyzed experiments in which subjects of different ages were asked to hold a button until they thought that a few seconds had passed. Importantly, while the experiments were conducted nothing else was going on. The study showed that, contrary to what was expected, older people judged these ‘empty intervals’ as being longer than younger people. However, these effects have been found to be reversible when the interval is filled with attention-grabbing elements. In their study, Craik and Hay (1999) asked subjects to make judgments about the sizes and shapes of some visual stimuli. They were then interrupted and asked how long they thought the task had lasted for. It was found that the older underestimated the duration to a greater extent than the younger. (Cf. Lustig, 2003, section 10.2.1). See also the discussion at the beginning of Levy et al. (2001).

⁹⁰ This idea is supported by a study in which subjects of various ages were asked to walk while memorizing something. The study suggests that older adults allocated more attention to walking while younger adults allocated more attention to the memorization task. See Lustig (2003, section 10.2.1).

what it takes to get around. This would explain why their days, weeks, and years feel like they are flying by.

One problem with this account, however, is that it presupposes that the challenges that older people face require more attention than those faced by younger adults and children. While it is true that what becomes challenging for people of different ages may very well vary, it still seems to be true that for most people and almost at every age there are daily activities that are challenging. Learning how to deal with the world and its complex social structure requires a lot of attention from children and adolescents. Taking care of children and providing for them are amongst the daily challenges faced by many young adults. For some of them, there are also the challenges that come with having a profession. Contrary to what seems to be the case, instead of younger ages being those at which time seems to pass the slowest, if this hypothesis were the case it would be perhaps only adults with no children and in a comfortable life position for whom time should be experienced as passing the slowest. The “golden years” should seem to drag on compared to the twenties, thirties, and forties.

As I turn to explain, the theory we have developed allows for a different and interesting way of accounting for this phenomenon that does not depend on attention. I offer it here only as a suggestion that, like the others, would have to be empirically tested.

Experiential Blackout

In experiencing an event we do not take in every single feature available to be experienced: every now and then we have short experiential blackouts. Consider again the dance show. Because of these blackouts, for instance, Peter could have failed to see some of the details

of the dancer's movements or to hear some bits of the music played during the show.⁹¹ Consider a creature for which these experiential blackouts are longer and more frequent than for Peter. Assume further that they both have the same level of attentiveness and that the quanta each takes in are roughly of the same duration. It follows that for the creature, fewer quanta would be involved in experiencing the same long-lived event than for Peter. Figure 31 depicts the situation for this creature, Peter, and a super-creature with no experiential blackout at all.

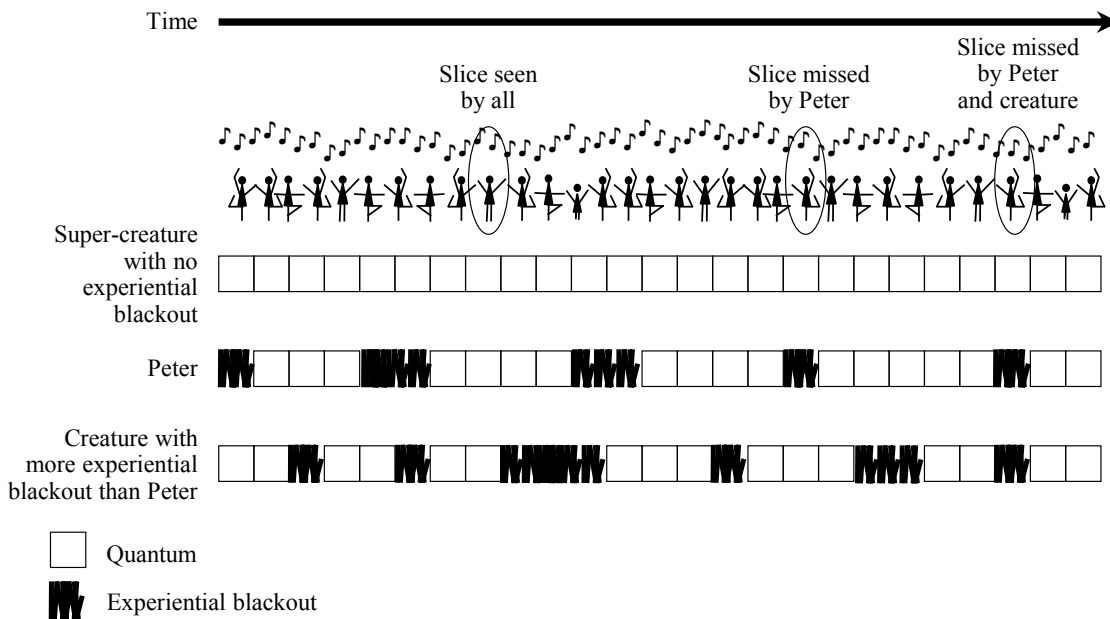


Figure 31. *Experiential blackout*

As illustrated, there will be, for example, slices of the dance that Peter misses but that the creature with no experiential blackout experiences. There will also be features of the show that both Peter and the creature with more extended and frequent experiential blackouts both fail to

⁹¹ An experiential blackout need not be accompanied by a corresponding cognitive blackout. That is, while we might fail to experience certain features of an object, in some cases we might still have cognitive access to them.

experience. Assuming that the levels of attentiveness and how they are split between the dance show and the subject's experiential features is held fixed for the three subjects, it follows from the experiential profile of each of the subjects and the theory of felt duration developed here that the creature with no experiential blackout will experience the dance show as lasting the longest. Peter will be next and the creature with more experiential blackouts will experience the dance as having the shortest duration.

Consider, for instance, the creature with no experiential blackout. Her experience of the show involves the largest number of experienced quanta. Because of this, other things being equal, she will notice more quanta than Peter and the other creature. She will thus form an impression of a larger number of them during the show. Hence, she will experience the event as lasting longer than do the other two subjects.

More generally, keeping other things equal, the felt duration of a long-lived event increases or decreases with an increase or decrease in the density of the quanta involved in experiencing the event. Since the effect of the experiential blackout is to decrease this density, the more experiential blackout, the lower the density of quanta involved in experiencing the event, and therefore the shorter the duration that the event is experienced as having. Increasing or decreasing the density of the experienced quanta involved in taking in an event, moreover, has no effects on how short-lived events are experienced. The only consequence of having a higher or lower density of quanta is that more or fewer short-lived events get to be experienced.

The suggestion, thus, is that as we age the length and frequency of these experiential blackouts increases. As illustrated in the example above, the consequence of this is that, keeping all else equal, the density of quanta involved in experiencing a long-lived event is lower for older adults. But then, their felt duration for long-lived events should be shorter than for younger

adults. Any given day, week, or year will thus have fewer experienced quanta than for those who are younger. Hence, older people would experience these as lasting for less time, and thus, as passing by more quickly. Since the days, weeks, and months of children would have, on average, more experienced quanta than those who are older, for them a school year would feel like an eternity compared to how their parents and grandparents experience it. The creature at the bottom of Figure 31 could serve to depict a subject considerably older than Peter.⁹²

If this hypothesis were true, it would not only be true that younger adults experience the duration of a day as lasting longer than the way older adults experience it. It would *also* be the case that younger adults experience *more* in a day. You would thus be better off not waiting too long to cash in that free day in the spa. Putting that dreadful operation off further, on the contrary, might save you some of the pain!

This hypothesis is independent of the previous one. Thus, it could be that both are true. The combined effects of having more experiential blackouts and allocating more attentional resources in ordinary tasks could be what explain why, compared to our younger years, as we age time seems to fly by.⁹³

⁹² As mentioned before, most experiments in the psychological literature involve very short periods of time. Since while in the testing environment the subject is paying attention to the experiment, it is less likely that experiential blackouts occur. It is only if an experiential blackout happens to coincide with the stimulus being presented that some effect would be found. To test this hypothesis, measuring the features experienced by subjects of different ages engaged in some long-term activity (perhaps lasting various hours) would be preferable. Lustig (2003) suggests something similar but for testing flickering rates of *attention* in older adults.

⁹³ An alternative way of accounting for ‘the speeding up of time’ phenomenon observed with aging would be if the approximate number system, as we age, produced more ‘undercounts’ of quanta. If quanta indeed overlap, another

OBJECTION FIVE

When *the memory hypothesis* was discussed in chapter 1, what was considered and responded to was what we might rather call *the long-term memory hypothesis*, the idea that it is facts having to do with how an experience is stored in long-term memory that account for our duration judgments. Against this hypothesis, it was pointed out that it makes the wrong predictions. For instance, when a fun party is later remembered, it is usually remembered as having lasted for a very long time. But the party was originally experienced as flying by!

All this is well and good but what is wrong with the idea that felt duration is the product of working memory? Would not this *working memory hypothesis* be a more relevant alternative to your theory?

RESPONSE

The main reason why the long-term memory hypothesis is incompatible with the theory I have developed is that, as mentioned above, it involves denying that the actual, concurrent experience of the event is what grounds the corresponding judgment about its duration. According to this view, it is the later memory of the event that underlies this judgment.

The working memory hypothesis, however, does not need to deny this. Indeed, what is called *working memory*, a system responsible for holding information for a brief amount of time, leaving it ready to be accessed and modified in different cognitive tasks, may be what is involved in producing our original experiences of the short-lived events around us. Thus, the short-term explanation compatible with the theory offered would be to argue that what the subjective pacemaker ‘counts’ are quanta (as opposed to non-overlapping quanta) and that, as we age, quanta tend to overlap less. Thanks to Fiona Macpherson for a helpful discussion on this last point.

memory hypothesis is not just compatible with the quantum theory of felt duration, but it may also be precisely what is involved in experiencing a quantum.

Note that if it is assumed that working memory could not be involved in producing the actual, original experiences of the events around us, then the working memory hypothesis, just as the long-term memory hypothesis, would indeed be incompatible with the quantum theory of felt duration. It would amount to the claim that facts about how an experience is stored in working memory, as opposed to facts about how the event is originally experienced, are what explain why, upon retrieval, the event in question is judged to have lasted a particular amount of time. But, unlike in the case of long-term memory, in which the memories are retrieved *after* the original experience has occurred—and must therefore be numerically distinct from these experiences—there is no reason to assume this in the case of the short-term memory involved in working memory.⁹⁴

⁹⁴ For instance, see Hassin et al. (2009) for a discussion of the widely held idea that the processes and products of working memory are conscious. This paper also presents some studies suggesting that working memory should be expanded to include also non-conscious processes and products. Thanks to Adam Lerner for a helpful exchange on this and for sharing this reference with me. Thanks to Maite Ezcurdia and Agustín Rayo for a helpful discussion about this fifth objection.

References

- Agrillo, C., A. Ranpura, and B. Butterworth (2010). Time and numerosity estimation are independent: Behavioral evidence for two different systems using a conflict paradigm, *Cognitive Neuroscience*, 1 (2), 96-101.
- Anderson, N.D., T. Lidaka, R. Cabeza, S. Kapur, A. R. McIntosh, and F. I. M. Craik (2000). The effects of divided attention on encoding- and retrieval-related brain activity: A PET study of younger and older adults, *Journal of Cognitive Neuroscience*, 12, 775-792.
- Barth, H., N. Kanwisher, and E. S. Spelke (2003). The construction of large number representations in adults, *Cognition*, 86, 201-221.
- Baum, S.K., R. L. Boxley, and M. Sokolowski (1984). Time perception and psychological well-being in the elderly, *Psychiatric Quarterly*, 56, 54- 61.
- Block, R., P. Hancock, and D. Zakay (1998). Human Aging and Duration Judgments: A Meta-Analytic Review, *Psychology and Aging*, 13 (4), 584-596.
- Brentano, F. (1988). *Philosophical Investigations on Space, Time and The Continuum*, Beckenham: Croom Helm.
- Broad, C. D. (1923). *Scientific Thought*, London: Routledge and Kegan Paul.
- Cantlon, J.F., S. Cordes, M. E. Libertus, and M. Brannon, (2009). Comment on “Log or linear? Distinct intuitions of the number scale in Western and Amazonian indigene cultures”, *Science*, 323, 38b.
- Chesney, D., Gelman, R., (2012). Visual nesting impacts approximate number system estimation, *Attention, Perception, and Psychophysics*, 74, 1104-1113.

- Chisholm, R. (1981). Brentano's Analysis of the Consciousness of Time, *Midwest Studies in Philosophy*, 6 (1), 3-16.
- Cordes, S., R. Gelman, C. R. Gallistel, and J. Whalen (2001). Variability signatures distinguish verbal from nonverbal counting for both large and small numbers. *Psychonomic Bulletin & Review*, 8, 698-707.
- Craik, F.I.M. and J.F. Hay (1999). Aging and judgments of duration: effects of task complexity and method of estimation, *Perception and Psychophysics*, 61, 549-560.
- Dainton, B. (2006). *Stream of Consciousness*, 2nd ed., London: Routledge.
- Dehaene, S. E. Dupoux, and J. Mehler (1990). Is numerical comparison digital? Analogical and symbolic effects in two-digit number comparison. *Journal of Experimental Psychology: Human Perception and Performance*, 16, 626-641.
- Dehaene, S. (1997). *The number sense*, Oxford: Oxford University Press.
- Di Lollo, V. (1977). Temporal Characteristics of Iconic Memory, *Nature*, 267, 241-243.
- Drake, C., and M. -C. Botte (1993). Tempo sensitivity in auditory sequences: Evidence for a multiple-look model, *Perception and Psychophysics*, 54, 277-286.
- Eagleman, D. M. and V. Pariyadath (2009). Is subjective duration a signature of coding efficiency?, *Philosophical Transactions of the Royal Society*, 364, 1841-1851.
- Eagleman, D. M., P. U. Tse, D. Buonomano, P. Janssen, A.C. Nobre, A. O. Holcombe (2005). Time and the brain: How subjective time relates to neural time, *The Journal of Neuroscience*, 25 (45), 10369-10371.

- Eagleman, D.M. (2005). How does the timing of neural signals map onto the timing of perception?, in Nijhawan, R. (ed.), *Problems of space and time in perception and action*, Cambridge: Cambridge University Press.
- Eagleman, D. M., <http://eaglemanlab.net/time>, accessed on September 25th, 2012.
- Eisler, H., A.D. Aisler, and Å. Hellström (2008). Psychophysical issues in the study of time perception. In S. Grondin (ed.) *Psychology of time* (75-110), Bingely: Emerald Group.
- Elvevåg, B., T. McCormack, A. Gilbert, G.D.A. Brown, D. R. Weinberger, and T. E. Goldberg (2003). Duration judgments in patients with schizophrenia, *Psychological Medicine*, 22, 1249-1261.
- Feigenson, L., S. Dehaene, and E. S. Spelke (2004). Core systems of number, *Trends in Cognitive Sciences*, 8, 307-314.
- Franck, N., A. Posada, S. Pichon, and P. Haggard (2005). Altered subjective time of events in schizophrenia, *Journal of Nervous and Mental Disease*, 193, 350-353.
- Friedman, W. J. and S. M. J. Janssen (2010). Aging and the speed of time, *Acta Psychologica*, 134, 130-141.
- Gallant, R., T. Fidler, and K. A. Dawson (1991). Subjective time estimation and age, *Perceptual and Motor Skills*, 72, 1275-1280.
- Gilmore, C., N. Attridge, and M. Inglis (2011). Measuring the approximate number System, *The Quarterly Journal of Experimental Psychology*, 64 (11), 2099-2109.
- Grondin, S. (2010). Timing and time perception: A review of recent behavioral and neuroscience findings and theoretical directions, *Attention, Perception, and Psychophysics*, 72 (3), 561-582.

- Halberda, J., and L. Feigenson (2008). Developmental change in the acuity of the “number sense”: The approximate number system in 3-,4-,5-, and 6- year olds and adults, *Developmental Psychology*, 44, 1457-1465.
- Hassin, R. R., J. Bargh, A. D. Engell, K. C. McCulloch (2009). Implicit working memory, *Consciousness and Cognition*, doi: 10.1016/j.concog.2009.04.003
- Husserl, E. (1964). *The Phenomenology Of Internal Time-Consciousness*, Bloomington: Indiana University Press.
- Ivry, R. B. and J. Schlerf (2008). Dedicated and intrinsic models of time perception, *Trends in Cognitive Sciences*, 12, 273-280.
- James, W. (1890). *The Principles of Psychology*, Vol.1, New York: Henry Holt and Co.
- Johnston, M. (2004). The obscure object of hallucination, *Philosophical Studies*, 120, 113-183.
- Joubert, C.E. (1990). Subjective expectations of the acceleration of time with aging, *Perceptual and Motor Skills*, 70, 334.
- Joubert, C.E. (1984). Structured time and subjective acceleration of time, *Perceptual and Motor Skills*, 59, 335-336.
- Joubert, C.E. (1983). Subjective acceleration of time: Death anxiety and sex differences, *Perceptual and Motor Skills*, 57, 49-50.
- Karmarkar, U.R., and D. V. Buonomano (2007). Timing in the absence of clocks: Encoding time in neural network states, *Neuron*, 53, 427-438.
- Lee, Geoffrey (2009). *Essays on consciousness, space, time, and space-time*, New York University, ProQuest, UMI Dissertations Publishing, 3380211.

REFERENCES

- Lee, K-H., R. S. Bhaker, M. Ashok, R. W. Parks, P. B. L. Birkett, and P. W. Woodruff (2009). Time perception and its neuropsychological correlates in patients with schizophrenia and in healthy volunteers, *Psychiatry Research*, 166, 174-183.
- Lemlich, R. (1975). Subjective acceleration of time with aging, *Perceptual and Motor Skills*, 41, 235-238.
- Levy, B., P. Jennings, and E. J. Langer (2001). Improving attention in old age, *Journal of Adult Development*, 8 (3), 189-192.
- Lockwood, M. (2005). *The Labyrinth of Time*, Oxford: Oxford University Press.
- Lustig, C. (2003). Grandfather's clock: Attention and interval timing in older adults, in W. H. Meck (ed.) *Functional and neural mechanisms of interval timing*, 2003, CRC Press, 261-293.
- MacAuley, J.D., M. R. Jones, S. Holub, H.M. Johnston, & N.S. Miller (2006). The time of our lives: Life span development of timing and event tracking, *Journal of Experimental Psychology: General*, 135, 348-367, doi: 10.1037/0096-3445.135.3.348
- Maricq, A.V. and R. M. Church (1983). The Differential Effects of Haloperidol and Methamphetamine on Time Estimation in the Rat, *Psychopharmacology*, 79, 10-15.
- Maricq, A.V., S. Roberts, and R.M. Church (1981). Methamphetamine and time estimation, *Journal of Experimental Psychology: Animal Behavior Processes*, 7, 18-30.
- Meck, W. H. (1996). Neuropharmacology of timing and time perception, *Cognitive Brain Research*, 3, 227-242.

REFERENCES

- Meck, W. H., and R. M. Church (1983). A mode control model of counting and timing Processes, *Journal of Experimental Psychology: Animal Behavior Processes*, 9(3), 320-334, doi:10.1037/0097-7403.9.3.320
- Ogden, R. S, J. H. Wearden, D.T. Gallagher, and C. Montgomery (2011). The effect of alcohol administration on human timing: A comparison of prospective timing, retrospective timing and passage of time judgments, *Acta Psychologica*, 138, 245-262.
- Pariyadath, V. and D. M. Eagleman (2007). The effect of predictability on subjective duration, *PLoS ONE* 2, e1264.
- Penney, T. B. and L. Vaitilingam (2008). Imaging time, in S. Grondin (ed.), *Psychology of time*, 261-294, Emerald Group.
- Phillips, Ian B. (2009). *Experience and time*, PhD Dissertation, University College London.
- Piazza, M., A. Facoetti, A.N. Trussardi, I. Berteletti, S. Conte, and D. Lucangeli (2010). Developmental trajectory of number acuity reveals a severe impairment in developmental dyscalculia, *Cognition*, 116, 33-41.
- Piazza, M., P. Pica, V. Izard, E. Spelke, and S. Dehaene (2013). Education enhances the acuity of the nonverbal approximate number system, *Psychological Science*, doi: 10.1177/0956797612464057
- Pica, P., C. Lemer, V. Izard, and S. Dehaene (2004). Exact and approximate arithmetic in an Amazonian indigene group, *Science*, 306, 499-503.
- Rammsayer, T. H. (1999). Neuropharmacological evidence of different timing mechanism in humans, *Quarterly Journal of Experimental Psychology*, 52B, 273-286.

- Rammsayer, T. H. (1990). Temporal discrimination in squizophrenic and affective disorders: evidence for a dopamine-dependent internal clock, *The International Journal of Neuroscience*, 53, 11-120.
- Rammsayer, T. H., and S. D. Lima (1991). Duration discrimination of filled and empty auditory intervals: Cognitive and perceptual factors, *Perception & Psychophysics*, 50, 565-574.
- Revkin, S. K., M. Piazza, V. Izard, L. Cohen, and S. Dehaene (2008). Does subitizing reflect numerical estimation? *Psychological Science*, 19(6), 607-614.
doi:10.1111/j.1467-9280.2008.02130
- Stetson, C., M. P. Fiesta, and D. M. Eagleman (2007). Does Time Really Slow Down during a Frightening Event? *PLoS ONE* 2 (12), e1295.
- Strawson, G. (1999). The Self and the Sesmet, *Journal of Consciousness Studies*, 6, 99-135.
- Taves, E. H. (1941). Two mechanisms for the perception of visual numerousness, *Archives of Psychology*, 37 (265).
- Treisman, M. (1963). Temporal discrimination and the indifference interval: Implication for a model of the 'internal clock.', *Psychological Monographs*, 77 (13), 1-31,
doi: 10.1037/h0093864
- Tse, P.U., J. Intriligator, J. Rivest, and P. Cavanagh (2004). Attention and the subjective expansion of time, *Perception and Psychophysics*, 66, 117-1189.
- Tuckman, J. (1965). Older persons' judgments of the passage of time over the lifespan, *Geriatrics*, 20, 136-140.

REFERENCES

- Ulrich, R., J. Nitschke, and R. Rammsayaer (2006). Cross modal temporal discrimination: Assessing the predictions of a general pacemaker-counter model, *Perception and Psychophysics*, 68, 1140-1152.
- Van Wassenhove, V., D. V. Buonomano, S. Shimojo, and L. Shams (2008). Distortions of Subjective Time Perception Within and Across Senses, *PLoS ONE* 3(1), e1437.
- Walker, J. L. (1977). Time estimation and total subjective time, *Perceptual and Motor Skills*, 44, 527-532.
- Wittmann, M., and S. Lehnhoff (2005). Age effects in perception of time, *Psychological Reports*, 97, 921-935.
- Zahavi, D. (2008). *Subjectivity and Selfhood*, MIT Press.
- Zelaznik, H.N., R. M. C. Spencer, and J.G. Doffin (2000). Temporal precision in tapping and circle drawing movements at preferred rates is not correlated: Further evidence against timing as a general purpose ability, *Journal of Motor Behavior*, 32, 193-199.