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# The Flow of Time as a Perceptual Illusion

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This article discusses theories and evidence on the flow of time as a perceptual illusion. The flow of time is said to be a stubborn illusion, although it has never been experimentally verified. There is a high-level flow of time (the experiential phenomenon of the past, present, and future), as well as a low-level flow of time, *happening*, which includes spatial change (motion). The hypothesis is that the latter, happening, component of the flow of time is a perceptual illusion. Previous research reveals that motion perception occurs in discrete processing epochs, frames, or snapshots. Apparent motion is painted onto each snapshot, and motion is not experienced because of a change in position between two consecutive snapshots but is represented within a single snapshot. When people view video scenes of a walking man and toasting bread with a wide range of interstimulus intervals, fewer of them could "see it happening" as the interstimulus interval was increased. This suggests that happening, whether involving a color change or a motion, is a frequency-dependent percept. It can be eliminated, for example, by choosing the appropriate stimulus frequency. The low-level component of the flow of time is therefore a perceptual illusion.

Keywords: time, time perception, flow of time, percept, illusion

Einstein said that "the past, present and future are only illusions, even if stubborn ones," that create a (false) impression that time is flowing (Davies, 2002, p. 41). However, no experimental evidence supports that contention. Before investigating the hypothesis that the flow of time is an illusion, we shall examine what is meant by "flow of time," a phenomenon which has been discussed in detail by

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Foundalis (2008), Hameroff (2003), Penrose (1989) and Smart (1980). It appears that the sense that time is flowing may be a more complicated phenomenon than is generally thought. There are actually two components to the flow of time (Davies, 1996) that should be distinguished. The commonly used expression, "flow of time," refers to the experiential phenomenon of events seeming to move from the future into the present and then into the past, a moving present that seems to flow like a river, hence the term (Segal, 2004). The experimental phenomenon of a moving present is what we will refer to as a high-level component of the flow of time. We use the term "high level" because as an experiential phenomenon it involves a somewhat higher (more complicated) cognition.

The high-level flow of time is in contradistinction to what we refer to as a low-level flow of time — the experiential phenomenon one receives from perceptual encounters such as spatial change (motion), color change, and auditory change. The low-level flow of time involves a less complicated perception, similar to that of fundamental or primary sensations. An exploding volcano is a low-level example. It involves the perception of change for three sensory modalities (the movement of the lava, the changing sky color, and the sound of the explosion). We focus on the low-level flow of time in this article, and it is the component that we hypothesize to be a perceptual illusion.

To clarify the meaning of the low-level flow of time, Gibson (1975) argued that "a sequence of external stimuli . . . provide[s] a *flow of change*, and it is this we perceive rather than a flow of time as such" (p. 299). He added that "the observer perceives both what is altered and what remains unaltered in the environment" (p. 298). Park (1999) agreed, suggesting that "discussions of time become more clear if one drops the word 'time' entirely and substitutes one of the words '*event*' or 'change' " (p. 20). Block (1998) expanded Gibson's argument and claimed that successive changes of events provide a source for the common spatial representation of the flow of time, "a straight line being steadily drawn in one direction" (p. 120). All three theorists seem to agree that avoiding the word "time" makes it easier to understand what is meant by the flow of time. At the very least, the expression "flow of time" is best replaced with the expression "flow of events."

However, there is a caveat. Participants in our studies (Gruber and Block, 2012) had difficulty expressing their perception when they were required to use phrases like flow of time or flow of events. Empirically, we found that the best term was *happening* (e.g., "Yes, I could see it happening. I sensed his motion"; or "No, I could not see it actually happening. But the individual slides told me he must have gone from one side to the other." Happening is a percept not only for spatial change but color and sound change as well.

Advocates of the notion that happening (the low-level flow of time) is an illusion include most post-Einstein physicists (Barbour, 1997, 2000; Greene, 2005). This is because the block universe theory of Einstein (Davies, 2002) suggested

that the universe is in essence a four-dimensional spacetime manifold, a universe consisting of slices of spacetime and one in which all of the events within each slice are said to be *just there*. However, the notion that events are just there does not mean that an observer should be able to perceive them simultaneously. At any point in time, the theory expects an observer to experience an event and also the memory of a past event. The next point in spacetime should result in a similar experience but without a special connection, a flow or a happening attributable to the adjacency of two events. More specifically, there is no need to account for the experiential phenomenon of motion in this well-accepted theory. A few theorists advocate the notion that the classic interpretation of the block universe theory is not correct. On the basis of chaos theory and irreversibility principles, Prigogine (1980) suggested that the subtle physics of irreversible processes make the flow of time an objective aspect of the world — not an illusion. In his spacetime dynamics theory, Elitzur (1991, 1996) argued much the same, as did Ellis (2008), that spacetime "grows" in the future direction.

*Illusions and Happening*

Anstis (2009) [see also Gregory, 1991; Zakay, 2009; Zakay and Bentwich, 1997] reviewed the meaning of the term "illusion." The simplest way to know if a percept is an illusion is whether or not it contradicts any laws of physics. In the event that is not possible, one must look towards the characteristics of illusions. An illusory percept, unlike the percept of external stimuli, is one that if removed or eliminated, no consequence (such as the loss of incoming information) should result.

The present hypothesis is that happening (the low-level flow of time) is a perceptual illusion. Therefore, to assess the validity of that hypothesis one should be able to demonstrate that (1) happening can be eliminated (i.e., Einstein's illusion is not all that stubborn), and (2) when eliminated, the percept of happening is irrelevant.

*Happening for Spatial and Color Events*

Noting that the illusion of the phi phenomenon is stimulus frequency-dependent (Steinman, Pizlo, and Pizlo, 2000) in that it exists only at certain frequencies, we decided to determine whether or not happening is also a frequency-dependent percept. If it is, perhaps it is an illusion similar to the phi phenomenon. Specifically, we decided to determine the effects of major stimulus frequency alterations on the low-level flow of time (happening) for both spatial and color stimuli as a test of the hypothesis (Block and Gruber, in press; Gruber and Block, 2012). In these experiments, video scenes of a walking man and bread turning brown in a toaster, using interstimulus intervals of 0.5, 3.0, and 7.0 s, were shown

to participants.[1] Participants judged whether or not they could see motion of the walking man and the toast changing color. More specifically, they had to judge whether the events (walking or toasting) had actually "happened" or those that "must have happened."

As the interstimulus interval increased, fewer participants experienced happening. Specifically, at an interstimulus interval of 0.5 s, most participants in the walking and toasting conditions responded with "happening." At an interstimulus interval of 7.0 s, many fewer participants in both conditions responded with "happening." What is important is that as the interstimulus interval increased beyond a critical level, the "flow of events" reverted to a "sequence of events" (cf. Gibson's [1975] sequence of external stimuli). Events became relatively static. Moreover, participants in the study perceived all relevant information from observation of the walking man, such as duration between stimuli and their chronology. Because the percept of happening (e.g., motion) could be eliminated without losing any relevant visual information, these results suggest that the flow of events (happening) is a frequency-dependent perceptual illusion.

*Change Detection and Motion Perception*

Similar results have been found by others, although their interpretations differed. Instead of using the term happening, some researchers use the term *change detection*, in particular, dynamic change versus completed change (for a review, see Rensink, 2002). Using an informal flicker paradigm, Hollingworth (2008) presented participants with one visual scene (for a duration of 250 ms) immediately followed by another (of that duration) that was slightly different (e.g., absence of a chimney that was previously present), while varying the interstimulus interval (200 ms, 1000 ms, or 5000 ms). Participants reported having a strong impression of "seeing the change occur" at 200 ms, a weaker impression at 1000 ms, and no impression of seeing the change occur at 5000 ms. Nakashima and Yokosawa (2012) basically replicated Hollingworth's experiment, and our results show similar decrements with progressively increasing interstimulus intervals but a shift to longer interstimulus interval values — perhaps because we used real life situations and asked specifically if motion was sensed.

[1]In our experiment (Block and Gruber, in press), ten frames were played, each for 100 ms, with an interstimulus interval between frames (stimuli) of 0.5, 3.0 and 7.0 s. In the case of the experiment involving a walking man, participants were asked to answer either: A — "Yes, I could see it happening. I sensed his motion across the parking lot"; or B — "No, I could not see it actually happening or sense his motion. But the individual slides told me he must have gone from one side to the other." In the case of the experiment involving toasting, participants were asked to answer either A — "Yes, I could see it actually happening. I saw it become toasted"; or B — "No, I could not see it actually happening. But the individual slides told me it must have become toasted."

Two studies examined motion perception at longer interstimulus intervals. Palmer (1986) presented participants with two points of light for 1.0 s and then after a variable delay (up to 8.0 s) moved one of the points of light to the side. Participants did not report movement beyond delays of 200 ms. Bex and Baker (1999) used moving arrays of textured micropatterns. In their pilot study, displacement of a single patch (at an interstimulus interval of 1.0 s) was not accompanied by the subjective appearance of movement. Our study (Block and Gruber, in press) importantly differs from theirs in that they involved multiple, sequential stimuli of complex biological scenes. It appears that the percept of motion is easier to elicit from multiple episodic events.

There are other examples in which interstimulus interval manipulation generates illusory percepts. As the interstimulus interval is altered for illusory element motion, it is replaced by group motion (Scott–Samuel and Hess, 2001). On a more familiar level, time-lapse photographers recognize that the stimulus duration has to be reduced to a critical level before a budding flower comes alive, becomes dynamic, and happens. Thumbing through a flipbook also results in a dynamic motion of the scene when the critical rate (stimulus duration) is reached.

*Illusions and Continuous Motion*

To further appreciate the fact that happening is frequency-dependent, we contrast the above results to the illusory percept of continuous motion by discrete sampling (Crick and Koch, 2003, 2007; VanRullen and Koch, 2003; VanRullen, Reddy, and Koch, 2010). The wagon-wheel illusion is perhaps the best experimental example. If the wheel is viewed in continuous (not stroboscopic) light and the rotation rate is increased, a speed is reached in which the wheel appears to turn in reverse. This phenomenon suggests that the brain undergoes a visual sampling rate of approximately 13 Hz. Koch (2004) suggested that motion is painted onto each snapshot, and that motion is not experienced because of a change in position between two consecutive snapshots. In essence, the brain creates an illusion of continuous motion. However, the wagon-wheel experiment does not prove that continuous motion does not actually occur. Even if it was a percept that could be eliminated, the percept of continuous motion is not irrelevant in the experiment: it is a percept that provides necessary information about the stimulus (the wheel location at any point in time).

The illusion from discrete sampling resembles the illusion that provides richness to our visual world when our vision is interrupted by saccades (Blackmore, Brelstaff, Nelson, and Troscianko, 1995). In addition, the discrete temporal sampling rate (13 Hz) is close to the predicted rate of discrete conscious events in the Penrose–Hameroff model for what the researchers called orchestrated objective reduction (Orch OR), which is estimated at 40 Hz in some cases (Hameroff, 2001; Woolf and Hameroff, 2001).

*The Illusion of Music*

One other related frequency-dependent illusion is an auditory one — music. Although commonly thought of as a quale (Gregory, 1998; for a review of qualia see Duch, 2005), music is a superimposition of a non-informational illusory percept on an underlying stimulus complex. It is a superimposed aesthetic percept on the physical perception of the auditory stimuli (e.g., pitch, frequency, and volume). Music is also a frequency-dependent percept. Consider the four most recognized musical notes from Beethoven's Fifth Symphony. Anyone who has participated in a symphony orchestra, and who has played those four notes at progressively increasing intervals between them, knows that when one reaches an interval of 4.0 s between notes, Beethoven's Fifth Symphony is no longer identifiable to many listeners and does not even sound like music.

Some patients suffer a disorder involving a deficit in musical memory and recognition despite normal hearing, a condition referred to as amusia. A few of these amusia patients, when listening to a symphony, may hear all the sounds (pitch, frequency, and volume) that emanate from the musical instruments but simply do not experience music (Sacks, 2007). Clearly, music is irrelevant for auditory information purposes. Unlike other qualia (e.g., color which is not irrelevant for information purposes), music is also a perceptual illusion. As mentioned above, happening includes spatial change (motion), color change, and auditory change. Music is an example of an auditory change that happens to be a superimposed perceptual illusion. In that sense it is very much related to the illusory percept of motion.

*Specious Present*

The specious present (Block, 1979; Gruber, 2008; Kinsbourne and Hicks, 1990; Ruhnau, 1997), often referred to as the *now*, has a duration that is ill-defined but is about 3.0 s for many perceptual phenomena (Pöppel, 1985, 1997), shorter than the original estimate of 6.0 s by William James (1890). Our pilot studies were done initially with an interstimulus interval of 3.0 s because it was suspected that as a result of by-passing the now (presenting the second stimulus more than 3.0 s after the first) the stimulus would become a relatively old memory.

We conjectured that upon retrieval of that older lower-density memory, to compare it to a more recent higher-density memory, the brain would likely not be able to superimpose an illusory percept upon the older, lower-density memories. Our finding that the happening percept was more completely lost at the 7.0 s interstimulus interval than at 3.0 s interstimulus interval reveals that the illusion is likely related to the frequency per se and not the by-passing of the now.[2]

[2]S.M. Anstis, personal communication, November, 10, 2010.

*Becoming versus Happening*

How does one reconcile the above findings with the spacetime dynamics theory (Elitzur, 1991, 1996), Prigogine's (1980) approach to uncertainty, and chaos theory which insist that "events are becoming," and therefore the flow of time is not illusory? It is our contention that the low-level flow of time is an illusion that is not incompatible with Prigogine's and Elitzur's theories. Implicit in their theories is that becoming leads to a percept for a single event, a percept that is characterized by awareness of the observer that the event has come into existence. The participants in our experiment actually did experience awareness for the onset of each frame of the walking person.

However, that awareness for a single event (stimulus) is not the same as the happening they experienced when serial frames (events) were presented. When the interstimulus interval was sufficiently prolonged, there was awareness for the emergence of each frame of the walking man, but not a percept of happening. The (low-level) flow of time (requiring two or more events) is a different experiential phenomenon than the awareness of a coming-into-existence of a single event (stimulus). "Becoming" is not "happening." However, the illusory percept of happening is not precluded from and does not contradict Prigogine's or Elitzur's theories.

*Other Speculations*

The suspicion that the motion component of happening is a perceptual illusion is not new. Based upon the observation that a few patients saw the world as a cinematographic sequence of stills (a condition referred to as *akinetopsia*), Sacks (2005b, p. 35) raised the question of whether the continuous passage of time and movement is an illusion, "whether in fact our normal visual experience consisted of a series of 'moments' which were then welded together." Referring to the neurological findings of Sacks (1970), Koch (2004) remarked that rare migraines temporarily inactivate cortical motion areas, "thereby depriving . . . patients of the illusion of motion" (p. 266). In other words, the illusion of motion is necessary for normal cerebral functioning.

Based on what we now know about the percept of the flow of time, it is possible to speculate as to what the perception of events would be like if it were possible to eliminate the illusion of happening (including motion) at high frequencies (short interstimulus intervals). Our best guess is that the visual world would look like a series of stills at a rate of approximately 13 Hz (the estimated discrete processing rate of the brain). However, unlike the perception of happening (motion) that people currently experience from a 13 Hz movie, the perception of motion while observing the series of stills would be absent. The experiential phenomenon at a 13 Hz rate would be as devoid of motion as observing one

frame of a movie every 7 s (the interstimulus interval in our experiments when almost all participants lost the percept of motion). The demonstration of that experiential phenomenon at high frequencies is a stubborn problem awaiting future experimentation. It would be ideal to eliminate the percept of happening without having to reduce the stimulus frequency. Then there would be no question that the percept of happening is an illusion. To that end, it may be necessary to use methods other than frequency variation (e.g., transcranial magnetic stimulation) that are effective in disrupting various forms of perceptual motion, such as apparent rotary motion (Ruzzoli, Gori, Pavan, Pirulli, Marzi, and Miniussi, 2011) and the motion after-effect illusion (Theoret, Kobayashi, Ganis, DiCapua, and Pascual–Leone, 2002). However, our findings reveal that frequency variation is a powerful method to study why time seems to flow.

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