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Is conscious perception a series of discrete temporal frames?

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ABSTRACT

This paper reviews proposals that conscious perception consists, in whole or part, of successive discrete temporal frames on the sub-second time scale, each frame containing information registered as simultaneous or static. Although the idea of discrete frames in conscious perception cannot be regarded as falsified, there are many problems. Evidence does not consistently support any proposed duration or range of durations for frames. EEG waveforms provide evidence of periodicity in brain activity, but not necessarily in conscious perception. Temporal properties of perceptual processes are flexible in response to competing processing demands, which is hard to reconcile with the relative inflexibility of regular frames. There are also problems concerning the definition of frames, the need for informational connections between frames, the means by which boundaries between frames are established, and the apparent requirement for a storage buffer for information awaiting entry to the next frame.

1. Introduction

Subjectively, conscious perception is smooth and continuous. Things move on from one moment to the next, and we perceive motion and all other forms of change (while they are going on) without any hint of discontinuity. Conscious percepts must have some level of temporal granularity, and that may be set by fundamental operating characteristics of neurons. That level of granularity could be far below the temporal resolution of perception, much as the level of granularity in a digital photograph, the pixel, is usually far below the resolution of the photograph that is detectable to the eye. The finest temporal resolution in perception is found in specialised processors such as echolocation mechanisms in bats and electric field fluctuation detectors in electric fish, which can detect temporal phenomena on the nanosecond time scale (Carr, 1993; Simmons, 1973, 1979). In humans, differences in arrival times of sound to the two ears can be resolved on a scale of microseconds (Grothe, 2003). There is no percept of temporal succession at that level, however. Instead, the percept is of spatial localisation of a single sound source, and this does not resolve into a percept of two successive sounds until the time difference is ~5 ms (Wallach, Newman, and Rosenzweig, 1949). This is an indication that the fundamental temporal resolution in conscious perception may be on the millisecond time scale but perhaps < 10 ms.

Some authors, however, have proposed a level of temporal resolution in conscious percepts that is much coarser than that. In general terms, the proposal is that perceptual experience is packaged into discrete temporal frames on the sub-second scale, and that the apparent flow and continuity of perceptual experience over time is a superficial phenomenon that is underlain by temporal discontinuity on a time scale of a substantial fraction of a second. The aim of the present paper is to review and assess such proposals. Table 1 sets out the structure of the review.

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Table 1
Contents.

1.1. What is a frame of conscious perception?

Most proposals have had little to say about how a frame should be defined, but it is possible to point to some general features that will suffice for the time being. A common feature of the definition of frames is that they mark a boundary between events that are perceived as simultaneous versus nonsimultaneous (e.g. Crick & Koch, 2003; Pöppel, 1997, 2009; VanRullen & Koch, 2003). Thus, all information within a given frame has experienced contemporaneity, and events can only be perceived as occurring at different times if they occur in different frames. This implies a certain level of co-ordination in perceptual processing: given that different processes are separate, both functionally and neuroanatomically, especially if they occur in different modalities, there must be some kind of process that effectively assigns their products to bins in a co-ordinated way, as the foundation for experienced contemporaneity. It is sometimes stated in addition that the partitioning of percepts into temporal frames is endogenous and not affected by times of occurrence of external events (Harter, 1967; Stroud, 1956; Ulrich, 1987). However, Haber and Hershenson (1973) proposed that a series of frames could be initiated by the onset of a stimulus and ended at the frame containing the termination of the stimulus. It is also sometimes argued that a frame represents an updating interval: in effect, frames represent the maintenance of information in a static representation, and a new frame starts when some process of frame construction or updating is completed (Kozma & Freeman, 2017; VanRullen, Zoefel, & Ilhan, 2014).

The extreme form of the frame hypothesis is that there is just a single frame (at a time) that encompasses all of perception. This extreme form is hardly every encountered in the literature. It seems to be implied in Stroud's (1956) proposal of a psychological moment, and is explicit in Pöppel (1997, 2009), where research evidence from multiple areas, supposedly converging on a common duration for a frame of conscious perception, is taken as evidence for the generality of the proposed frame. Most other authors have endorsed frames that are local, sometimes to modalities (usually vision), sometimes to defined activities, processes, or mechanisms within modalities, such as visual attention, and sometimes of variable duration.

1.2. Discrete frames and the subjective continuity of perceptual experience

An analogy is sometimes taken with film projection, originally by Ansbacher (1944) and Stroud (1956), and by others since, including Craig (2009a), Freeman (2006), Hogendoorn (2016), Kozma and Freeman (2017), McComas and Cupido (1999), and Pockett, Brennan, Bold, and Holmes (2011). In this analogy, the frame of conscious perception is equivalent to a single frame of a film in the gate of the projector, and the subjective fluency of conscious perception is equivalent to the continuity of the film as projected