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Vision: When The Clock Appears to Stop

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Eye movements produce a temporary loss of visual sensitivity known as saccadic suppression, and a distortion of space perception known as saccadic compression. A new study has reported a seemingly related phenomenon — chronostasis — in which one's perception of time also undergoes an illusory distortion during rapid movements of the eyes.

Most readers will admit that, at some point in their lives, they have wished that time would stand still, a desire that almost caused Goethe's Faust to lose his soul to Mephisto. Unfortunately, physics still seems to be quite a distance away from devising a method allowing us to modify the course of time, but there may be hope. An elegant new experiment has revealed that the brain deceives us into believing that time has frozen. Kielan Yarrow and his colleagues have investigated this 'chronostasis' effect during which time appears to stop [1].

For those who have not experienced the chronostasis illusion before, this is safe to try at home (compared with other methods of time travel). All that is required is a clock or a watch with a silent second hand or a digital display. Fixate on a point somewhere away from the timepiece and then rapidly shift your gaze to the face of the clock. Repeat this test several times and on some occasions you may notice that the clock appears to have stopped for a little while following the eye movement: the second hand seems to take longer to jump to the next position indicating passing of the first second than it does during subsequent second intervals.

In their first experiment, Yarrow *et al.* [1] quantified this 'frozen clock' illusion by asking subjects to make a saccadic eye movement from a fixation target to a numerical counter presented on a screen some distance away. The eye movement, the amplitude of which was 22°, triggered a counter to increase from 0 to 1, and subsequently to count up to the number 4 (Figure 1). All intervals between digits were maintained for one second, except for the first digit, the duration of which was variable. Subjects had to judge whether the first digit seen after the saccade lasted for a longer or a shorter duration than subsequent digits. By varying the presentation duration of the first digit, Yarrow *et al.* [1] determined that it only had to be present for 880 milliseconds after the eyes had reached it for subjects to perceive it as having lasted for one second. This demonstrates that an event that is stationary for exactly one second is perceived as lasting longer immediately following a saccadic eye movement towards it. On a clock face, the equivalent is to perceive the second as moving more slowly when you first look at it.

The perceived duration of the presence of the first post-saccadic target was shown to depend on the amplitude, and therefore duration, of the saccade. During a saccade of 55° amplitude, lasting 67 milliseconds longer than the one of 22°, the first counter digit needed to be present for 69 milliseconds less than in the previous condition in order to be perceived as lasting for 1 second. In other words, the further away you look from a watch the slower that first second will appear when you refixate. This almost perfect match between the duration of an eye movement and that of perceived chronostasis is striking and provides powerful evidence for the notion that the brain constructs perceptual continuity across saccades.

Rapid eye movements are accompanied by blurring of the retinal image and reduced visual sensitivity. As a consequence, it can be difficult for the brain to determine the time of occurrence of intra-saccadic events accurately. The mechanism of chronostasis may be a strategy for backdating such events to a time before the eyes were in motion in order to preserve perceptual continuity.

Yarrow *et al.* [1] went on to demonstrate that the illusion of the stopped clock cannot be explained simply by a shift of the retinal position onto which the image of the target is projected. When subjects are asked to not perform a saccade but the position of the counter is moved into their point of fixation instead, the duration of the first digit presentation is perceived accurately. This is also the case when subjects keep fixating the initial target and the counter maintains its eccentric position.

The reorientation of gaze to a novel position in the visual field is frequently taken as a synonym for an overt shifting of attention to a different location in space [2]. It therefore remained a possibility that chronostasis does not occur because of the actual movement of the eyes, but rather that it is associated with the redirecting of spatial attention. To challenge this explanation, Yarrow *et al.* [1] ran a control experiment in which subjects were asked to attend to the saccadic target before they shifted their gaze. In spite of the fact that subjects had performed an attentional shift towards the target before they initiated the eye movement, the perception of chronostasis continued to persist and had similar temporal properties, indicating that an attentional shift alone is unlikely to account for the perception of chronostasis.

In a further control experiment, Yarrow *et al.* [1] tested whether time would still appear to freeze when the spatial continuity of the saccadic target was disrupted. Again, the saccadic eye movement triggered the running of the counter, but this time the counter was simultaneously displaced laterally by a small amount. Such a displacement occasionally went

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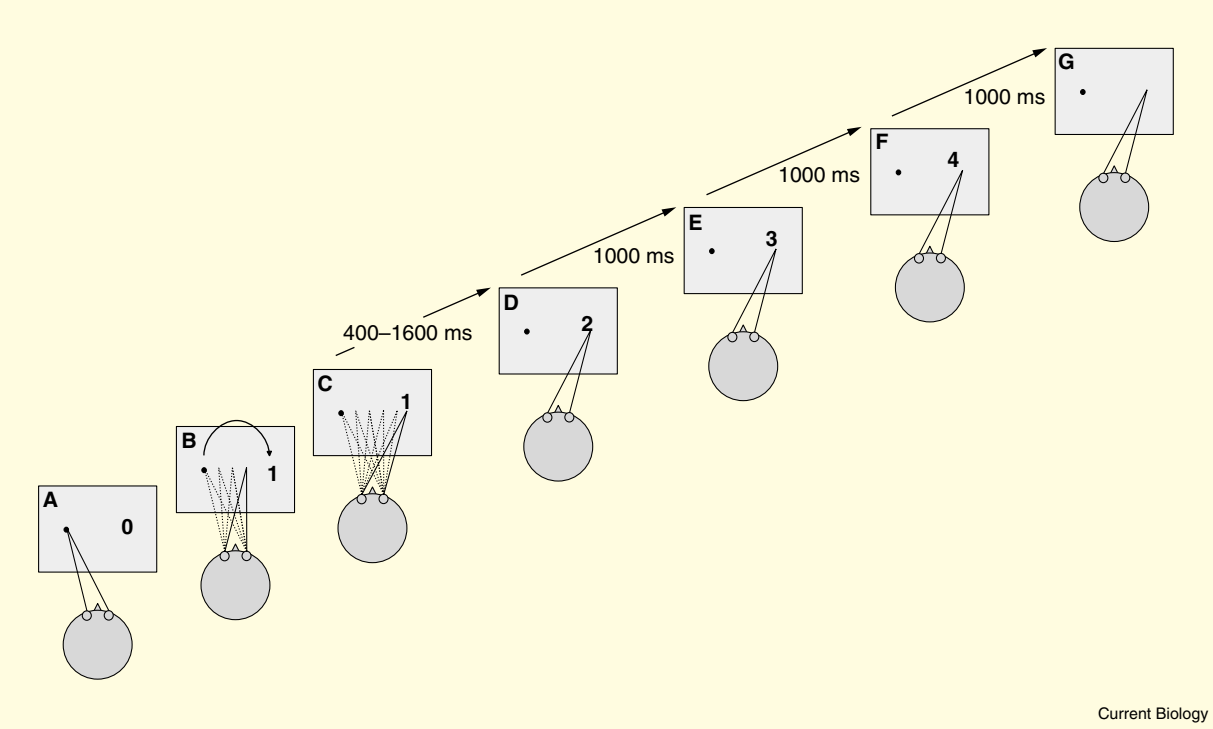


Figure 1. Schematic illustration of the method used in experiment 1 by Yarrow *et al.* [1].

The subject fixates a target on the screen and initiates the trial by pressing a button (A). Subsequently, the subject performs a voluntary saccadic eye movement towards the numerical counter presented on the other side of the screen. The saccade triggers the counter to change digits from 0 to 1 (B). After the eyes have reached the counter target, the digit 1 stays on the screen for a variable time ranging from 400 ms to 1600 ms (C). The subject keeps fixating the counter, which subsequently changes to the digits 2, 3 and 4, which all are presented for a duration of 1000 ms (D–F). After presentation of the final counter digit, the subject has to make a forced choice on whether digit 1 was visible for a shorter or a longer duration than the subsequent digits (G). By varying the presentation duration of the first digit according to the subject's responses, the necessary duration for it to be perceived to have lasted equally long as the other counter digits was determined using Modified Binary Search, a psychophysical threshold algorithm [12].

unnoticed by the observer, but when subjects did perceive the displacement, chronostasis did not persist and the duration of the first digit was judged veridically.

In those trials where subjects were unaware of the spatial shift of the target, however, some meaningful effect of chronostasis was obtained. This demonstrates that the perceived onset of a perceptual event that occurs during a saccadic eye movement is only pre-dated to have started at the onset, or slightly before, the beginning of the eye movement when observers perceive it to have been spatially invariant during this time. In other words, time stands still, or is backdated, from the beginning (or as we shall see from just prior to the beginning) of the eye movement only if the world remains the same during the eye movement; if the world changes, time begins again.

Yarrow *et al.* [1] propose an explanation for the apparent dependence of the illusory perception of temporal continuity on the spatial constancy of the saccadic target. As a result of the reduced visual acuity during a rapid eye movement, positional changes of objects in the visual scene cannot be detected reliably. An observer's brain will assume, however, that the intended target of the eye movement will have maintained its spatial location if the saccade lands successfully. As an extension of this inference, it will also be assumed that the scene found at the end of a saccade will have been the same when the eye movement was initiated. If the target changes its position noticeably during a saccade, the perception of object constancy in space is violated and, consequently, chronostasis is not perceived.

Intriguingly, the onset of chronostasis can be extrapolated to begin around 50 milliseconds before the eyes start to move, and therefore shares a suspiciously coincidental time window with two other perceptual phenomena linked to rapid eye movements: saccadic suppression and saccadic compression [3]. During saccadic suppression [4,5], sensitivity of mainly magnocellular visual processing is largely reduced [6], perhaps in order to save the visual system from processing a retinal image that would be heavily blurred because of the high velocity at which the eyes are moving. Saccadic compression refers to a bias in the perceived location of stimuli towards the endpoint of the saccade [7–9], and may reflect an anticipatory spatial reorientation of perceptual mechanisms.

This novel description of a perceptual illusion opens up a number of interesting experimental questions that await to be addressed. One may wonder, for example, whether chronostasis only exists in the visual-oculomotor modality, or whether it would also occur in other sensorimotor systems. Is a similar

effect obtained when, say, an arm movement is made from one tactile target to another — do things 'feel' to have lasted for longer? Furthermore, what happens across modalities? Is chronostasis abolished when one perceives an auditory rhythm, or a clock ticking audibly during an ocular gaze shift, or does it persist? Most revealing, however, will be the search for the neural sources underlying the illusory backwards extension of time and the identification of the extent to which chronostasis, saccadic suppression and saccadic compression share a common physiological substrate.

When the novelist Julio Cortazar [10] wrote "time is born in the eyes, everybody knows that" he may not have known how close he was to the biological truth. Even the more biologically sophisticated Huxley [11] may have been surprised at his accuracy.

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