Exp Brain Res (2003) 149:527–529
DOI 10.1007/s00221-003-1376-x

RESEARCH NOTE

**Junghyun Park · Madeleine Schlag-Rey · John Schlag**

# Voluntary action expands perceived duration of its sensory consequence

Received: 25 October 2002 / Accepted: 21 January 2003 / Published online: 26 February 2003


**Abstract** When we look at a clock with a hand showing seconds, the hand sometimes appears to stay longer at its first-seen position than at the following positions, evoking an illusion of chronostasis. This illusory extension of perceived duration has been shown to be coupled to saccadic eye movement and it has been suggested to serve as a mechanism of maintaining spatial stability across the saccade. Here, we examined the effects of three kinds of voluntary movements on the illusion of chonostasis: key press, voice command, and saccadic eye movement. We found that the illusion can occur with all three kinds of voluntary movements if such movements start the clock immediately. When a delay is introduced between the voluntary movement and the start of the clock, the delay itself is overestimated. These results indicate that the illusion of chronostasis is not specific to saccadic eye movement, and may therefore involve a more general mechanism of how voluntary action influences time perception.

**Keywords** Time perception · Chronostasis · Temporal illusion · Voluntary action · Saccade

## Introduction

When we look at a clock or a watch with a silent second hand, the hand sometimes appears to stay much longer at its first-seen position than at the following positions. For a brief moment, the clock seems to have stopped. This is known as 'stopped clock' illusion or 'chronostasis'. Yarrow et al. (2001) recently reported that this illusory extension of perceived duration is linearly related to the duration of the saccadic eye movement made to look at the clock. There was no illusion if the eyes did not move. Showing also that the illusion disappears if the observer noticed the clock displacement during the saccade, these authors suggested that the illusion is intimately coupled to the saccade and serves as a mechanism for maintaining perceptual stability across the saccade (see also Thilo and Walsh 2002; Miall 2002).

Is the saccade really necessary to chronostasis? It has been demonstrated that our perception of an external stimulus depends on whether our own movement causes it and this effect diminishes as the delay between the voluntary action and the stimulus increases (Blakemore et al. 1999; Haggard et al. 2002). In the control (no saccade) condition of Yarrow et al.'s study, where no illusion was observed, the judged stimulus was triggered 500 ms after the observer's key press. Thus it is not clear whether the lack of a saccade or the insertion of a delay between the voluntary key press and the judged stimulus is responsible for the elimination of chronostasis in these control trials.

In the present study we sought to determine under what conditions the illusion of chronostasis occurs. We first tested if the illusion can occur with other types of voluntary movements than a saccade. Then, we examined the reason why the illusion disappears if a delay is inserted between the action and the judged stimulus.

J. Park (✉) · M. Schlag-Rey · J. Schlag
Department of Neurobiology, UCLA School of Medicine,
Los Angeles, CA, 90095-1763, USA
e-mail: jhpark@ucla.edu
Tel.: +1-310-8259852
Fax: +1-310-8252224

## Materials and methods

In Experiment 1, eight observers (aged 22–35 years, seven naive) were asked to look at a numerical counter presented on a computer monitor. The initial value of the counter was '0' and, when triggered, it shifted to '1' and increased until '4' (Fig. 1). The observers were to judge whether the duration of '1' (varied between 600 and 1400 ms) was longer or shorter than that of the subsequent digits '2' and '3' (1000 ms each) following a previous method (Yarrow et al. 2001). The observer adjusted the duration of '1' through a nulling procedure that rendered a matched estimate after five reversals. Four estimates with a random initial value between 600–1400 ms were obtained per condition, and then averaged for each subject. There were three conditions in which the counter was triggered: (1) immediately after the observer's key press; (2) 500 ms after the observer's key press; or (3) at random time. Each condition was tested in a separate block, with test order counter-balanced. In additional sessions of Experiment 1, two observers

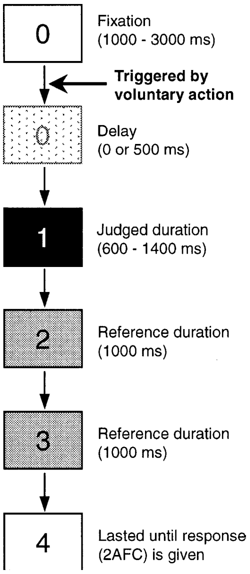


**Fig. 1** Schematic representation of the events in Experiments 1 and 2. The judged stimulus ('1') was triggered by voluntary movement (key press, voice command, or saccade) with or without a delay of 500 ms. In Experiment 3, the delay was compared to the reference intervals ('1'–'3', 1 s each)

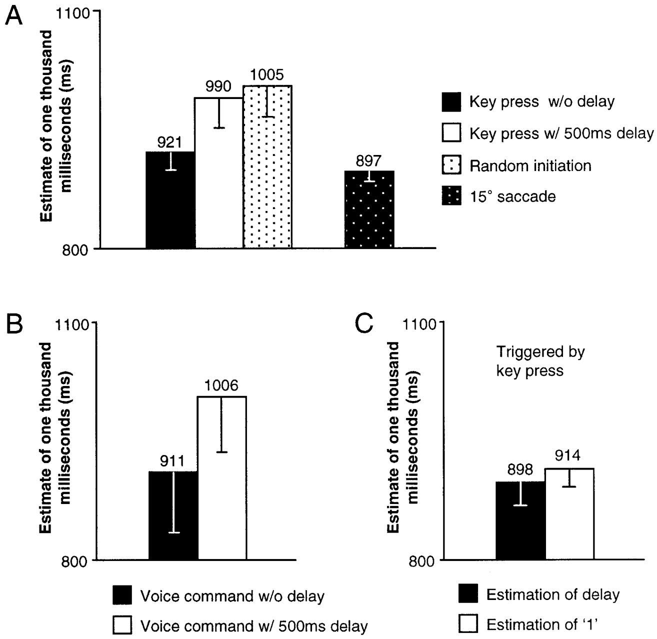


**Fig. 2** **A** The estimated time of 1000 ms in Experiment 1. Chronostasis occurs when the counter was triggered by key press or saccade without delay. However, chronostasis does not occur if there is a delay of 500 ms between the key press and the counter change or the change was not voluntarily controlled. **B** The estimated time of 1000 ms in Experiment 2. The similar pattern of results was obtained when the counter was triggered by voice command instead of key press. **C** The estimated time of 1000 ms in Experiment 3. Chronostasis occurs even when the delay was estimated instead of the duration of '1'. *Bars* show the standard deviation

were further tested in the condition where the counter was triggered one-third of the way into a 15° saccade to replicate and compare the present results with those of a previous study (Yarrow et al. 2001). Except for saccade trials, observers were required to fixate the counter throughout a trial.

Eye positions of two observers were recorded by an EyeLink gaze tracker (SR Research Ltd., Canada) at 250 Hz to trigger the counter in saccade trials and to ensure the stability of the eyes in key press trials. The observers maintained rigid fixation near the time of key press: in no key press trials did the eyes go out of a square window of ±2° around the digit during the critical period of ±250 ms around the time of key press.

In Experiment 2, the change of digit from '0' to '1' was triggered by the observers' voice command (saying 'go'), which was detected by a voice key, with or without a delay of 500 ms. Except for these changes, other procedures were the same as for Experiment 1. Five of the eight observers who had been involved in Experiment 1 were tested in this condition.

In Experiment 3, the duration of digits '1'–'3' was fixed to 1000 ms but the delay (from the time of the observer's key press to the change of digit to '1') was varied between 600 and 1400 ms. Observers were asked to adjust this delay until it matched the duration of subsequent digits through the same nulling procedure as in Experiments 1 and 2. Three of the five observers who had completed Experiments 1 and 2 were tested in this condition.

The digits (0.8×0.5°) were black on a gray background and were presented at the center of a 19-inch color monitor (120 Hz) at the viewing distance of about 57 cm. The experimental protocol was approved by the UCLA Office for the Protection of Research Subjects.

## Results

Experiment 1 tested whether chronostasis can occur with finger movement (i.e., key press). Figure 2A shows that when the counter started upon the key press without delay, observers overestimated the duration of '1': they perceived the duration of '1' to be the same as '2' and '3' (1000 ms) when it was presented for 921 ms. In contrast, when a delay of 500 ms was introduced between the key press and the start of the counter (as in control trials of Yarrow et al. 2001) or when the counter started at random time independently of the observer's behavior, the perceived duration of '1' was nearly veridical (the estimates of 1000 ms were 990 ms and 1005 ms, respectively). These last two values were significantly different from the first condition (paired t-tests, $P<0.001$ for both comparisons). As expected from the original study (Yarrow et al. 2001), the illusion (897 ms) also occurred when the counter was triggered in the middle of a 15° saccade.

To further generalize the result of Experiment 1, which suggested that chronostasis can occur with voluntary movements other than saccades, we tested a quite different type of voluntary movement in Experiment 2: voice command. The result was comparable to that of Experiment 1 (Fig. 2B). The chronostasis occurred when the counter started upon the voice command without delay, but did not if there was a delay of 500 ms between voice command and the start of the counter (the estimates of 1000 ms were 911 ms and 1006 ms, respectively; paired $t$-test, $P<0.05$).

Experiments 1 and 2 showed that the duration of a visual stimulus triggered by voluntary movement is overestimated only when there is no delay between the action and the judged stimulus. Why does the illusion disappear with a delay? Maybe voluntary action affects the perceived duration of the delay itself. To test this possibility, in Experiment 3, we asked the observers to estimate the delay from the time of key press to the start of the counter, instead of judging the duration of '1' as in Experiments 1 and 2. Figure 2C shows that observers overestimated the duration of the delay (the estimate of 1000 ms was 898 ms) in much the same way as they did for the duration of '1' triggered by key press without delay (the estimate of 1000 ms was 914 ms) (paired *t*-test, $P>0.54$). This suggests that when voluntary action triggers a visual stimulus with a delay, the delay itself is overestimated, as the stimulus would be, if there were no delay. Let us note that now the onset of the judged duration is defined only by the perceived time of key press, not by a visual change (i.e., '0'→'1' as in Experiment 1). Since the end of the judged duration is defined by a visual change in both tasks (i.e., '0'→'1' in Experiment 3; '1'→'2' in Experiment 1), the comparable results obtained in the two tasks suggest that the perceived timing of key press and that of digit change triggered by key press are not different.

## Discussion

The present results show that the illusion of chronostasis can occur with diverse types of voluntary movements, such as key press, voice command, and saccade. When voluntary action brings about a visual stimulus, the brain illusorily expands the perceived duration of the stimulus so that time temporarily appears to be slowed down.

However, the chronostasis as originally defined does not occur if the target stimulus does not follow the action immediately. In this situation, the event that is actually triggered by the action is a 'delay', and we have shown that it is the duration of this delay that is overestimated. It thus seems that the illusion of chronostasis would occur whenever we attempt to make a temporal estimation of a duration whose onset is triggered by voluntary action.

What could be the mechanism by which voluntary action influences time perception? One possibility is that the brain decreases the size of its time unit (or increases the oscillatory frequency of the temporal pacemaker) near the time of voluntary action. A transient increase in arousal (Treisman et al. 1994; Rose and Summers 1995) or attention (Zakay and Block 1996; Migliore et al. 2001) presumably associated with the movement preparation or execution may alter the pace of the internal clock. Another possibility is that the brain extends the percept of a visual event – caused by voluntary action – forward or backward in time without changing the unit of time. This temporal extension does not seem to be directed forward (i.e., at the offset), since the perceived duration of the event right after the one triggered by voluntary action was not affected. Alternatively, the timing of movement command signal may be assigned to (or capture) the timing of a sensory signal triggered by the movement, thereby extending the perceived duration backward in time (i.e., at the onset). Previous studies argued that the perceived timing of voluntary action precedes the onset of EMG by ~86 ms (Libet et al. 1983; Haggard 1999), and that the perceived timing (not duration) of a tone triggered by a key press is shifted earlier toward the action (Haggard et al. 2002). Furthermore, the result of our Experiment 3 showed that the perceived duration of an interval (i.e., delay) whose onset was defined by the perceived timing of voluntary action was overestimated just as the interval defined by sensory information. It is thus plausible that chronostasis occurs because the perceived timing of voluntary action, which is referred backward, captures the perceived timing of the sensory stimulus triggered by the action.

In conclusion, we have shown that the illusion of chronostasis occurs with various types of voluntary movements. Saccadic eye movement is not necessary to chronostasis. Chronostasis would occur whenever we attempt to estimate the duration of an event that is triggered by voluntary action. However, this does not necessarily exclude the possibility that chronostasis may also be produced by other means (for instance, a brief and salient sensory event immediately preceding the judged duration) than an action.

**Acknowledgements** We thank R. Tang and K. Fong for their technical help. This research was supported by USPHS grant EY-05879.

## References

Blakemore S, Frith CD, Wolpert DM (1999) Spatio-temporal prediction modulates the perception of self-produced stimuli. J Cogn Neurosci 11:551–559

Haggard P (1999) Perceived timing of self-initiated action. In: Aschersleben G, Bachmann T, Müsseler J (eds) Cognitive contributions to the perception of spatial and temporal events. Elsevier, Amsterdam, pp 215–227

Haggard P, Clark S, Kalogeras J (2002) Voluntary action and conscious awareness. Nat Neurosci 5:382–385

Libet B, Gleason CA, Wright EW, Pearl DK (1983) Time of conscious intention to act in relation to onset of cerebral activity (readiness-potential): the unconscious initiation of a freely voluntary act. Brain 106:623–642

Miall C (2002) Stopping the clock. Trends Cogn Neurosci 6:66

Migliore M, Messineo L, Cardaci M, Ayala GF (2001) Quantitative modeling of perception and production of time intervals. J Neurophysiol 86:2754–2760

Rose D, Summers J (1995) Duration illusions in a train of visual stimuli. Perception 24:1177–1187

Thilo KV, Walsh V (2002) Vision: when the clock appears to stop. Curr Biol 12:R135–R137

Treisman M, Cook N, Naish PLN, MacCrone JK (1994) The internal clock: electroencephalographic evidence for oscillatory processes underlying time perception. Q J Exp Psychol A 47:241–289

Yarrow K, Haggard P, Heal R, Brown P, Rothwell JC (2001) Illusory perceptions of space and time preserve cross-saccadic perceptual continuity. Nature 414:302–305

Zakay D, Block RA (1996) The role of attention in time estimation processes. In: Pastor MA, Artieda J (eds) Time, internal clock, and movement. Elsevier, Amsterdam, pp 143–164