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About the time-shrinking illusion in the tactile modality

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ABSTRACT

The aim of this study was to examine the occurrence of a so-called time-shrinking illusion in the tactile modality, while it had been tested so far mainly with auditory and visual stimuli. We examined whether the perception of an empty time interval marked by two brief tactile stimuli, S (240 ms), would be influenced by the presence of a preceding time interval, P (160, 240, or 320 ms). Results showed that S was underestimated when P was shorter than S. This underestimation appeared as a kind of perceptual assimilation between P and S, but S was not overestimated when P was longer. The underestimation was rather interpreted as a manifestation of the time-shrinking illusion.

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1. Introduction

Time perception is unique and fascinating for its amodal nature, i.e., it is associated with no specific sensory system (Grondin, 2001). Since we do not have sensory receptors that are dedicated specifically for time perception, temporal information must be reconstructed in the brain from pieces of information obtained through various sensory organs. The present study focused on the processing of duration below 1 s. Perception of such short duration seems important for daily activities such as communicating with others or having the motor control necessary for playing music or completing sport movements (e.g., Buonomano, 2007).

Given the potential amodal nature of time perception, it would make sense to ask whether duration processing changes depending on sensory modalities. Indeed, one of the main issues in time perception studies has been whether or not there is a central clock mechanism, which processes duration in general irrespective of the sensory modality of the inputs (e.g., Bueti, 2011; Grondin, 2010, in press). The concept of a central clock has dominated research in the field of time perception for a long period (e.g., Gibbon et al., 1984). However, there are reasons to believe that time perception would be modality-specific (Buonomano, 2007; Karmarkar & Buonomano, 2007). Indeed, the ability of discriminating intervals, expressed by the Weber fraction, changes according to the modality of marker stimuli (e.g., Grondin, 1993). Given these opposite perspectives concerning the modality dependency/independency of time perception, it would be interesting to examine whether a time-perception illusion that has been established with one modality could take place in other modalities.

In the present study, we focused on an illusory phenomenon that had been investigated mainly in the auditory modality, and examined whether the illusion occurs also in the tactile modality. This illusion is called *time shrinking* (e.g., Nakajima et al., 1991, 2004; see also ten Hoopen et al., 2008 for a review). When three successive short sounds mark two neighbouring time intervals (/t1/t2/; slashes denote short sound markers delimiting t1 and t2), the second interval (t2) can be underestimated to a considerable degree under certain temporal conditions. These conditions are when t1 is shorter than t2, and when the difference between t1 and t2 is smaller than about 100 ms (e.g., Nakajima et al., 1991). Time shrinking typically takes place when t1 is shorter than 200 ms (e.g., Nakajima et al., 2004). Since in most cases the perceived duration of t2 approaches that of t1, time shrinking can be considered to be a type of temporal assimilation between two neighbouring time intervals (Nakajima et al., 2004). However, a unique aspect of this assimilation is that it is asymmetric. While the perception of t2 is affected by the presence of t1 (Nakajima et al., 2004; Sasaki et al., 1998), the assimilation of t1 to t2 can occur, but only to a much smaller extent (Miyauchi & Nakajima, 2005).

Time shrinking has been observed in experiments with various psychophysical methods, including the method of adjustment (e.g., Nakajima et al., 2004), the method of constant stimuli (ten Hoopen et al., 1993), and the method of paired comparisons (e.g., Hasuo

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et al., 2011; Miyauchi & Nakajima, 2007). An electrophysiological study by Mitsudo et al. (2009) showed that the auditory temporal assimilation can be related to the activity in the right prefrontal area of the brain. For other sensory modalities, however, there are only limited studies. Arao et al. (2000) showed the existence of time shrinking with three successive brief flashes (visual markers). They reported that time shrinking took place in the visual modality as in the auditory modality, but for wider duration ranges: it appeared when the preceding time interval (t1) was 160–400 ms, and even when the difference between t1 and t2 was as large as 360 ms when t1 was 400 ms. Van Erp and Spapé (2008) found time shrinking for vibrotactile markers. They used the method of adjustment to measure the subjective durations of t2, which was similar to that in Nakajima et al. (1991, 2004) and Arao et al. (2000). However, throughout the range of t2 durations they used (i.e., 260, 300, 340, and 380 ms for t1 = 200 ms; 460, 500, 540, and 580 ms for t1 = 400 ms), the underestimation of t2 was constant and not dependent on the difference between t1 and t2. This finding is much different from what was found with auditory and visual modalities where, in both cases, the relationship between t1 and t2 was critical for the occurrence of time shrinking. This difference between the results in the tactile modality and those in the other modalities could have been caused by the fact that, in Van Erp and Spapé (2008), only conditions where t2 was longer than t1 were used. It seemed necessary to examine the occurrence of time shrinking in the tactile modality with a wider range of differences between t1 and t2, including conditions such as t1 > t2. Such observation should be important in further comparing the illusion between modalities.

In the present study, we investigated the occurrence of time shrinking in the tactile modality with three different relationships between t1 and t2: t1 < t2, t1 = t2, and t1 > t2. In audition (e.g., Nakajima et al., 2004) and vision (Arao et al., 2000), time shrinking typically took place when t1 < t2, and the amount of the illusion decreased as t1 became longer. If the tactile time shrinking reported by Van Erp and Spapé (2008) is not qualitatively different from auditory and visual time shrinking, the same pattern of results can be expected for the tactile modality: a decrease in the illusion as t1 increases.

2. Method

2.1. Participants

Twelve participants (9 females and 3 males)[1] were recruited at Laval University. Their mean age was 27.8 (SD = 7.02). They consented to their participation by signing a form approved by the institutional ethical committee, and received CAD$28 for their participation.

2.2. Stimuli and apparatus

Each tactile stimulus was a 20-ms electric signal. The voltage (stimulus intensity) was calibrated before the beginning of each session; it was fixed to a point at which participants could clearly perceive the stimuli but without any discomfort. The stimulus patterns are illustrated in Fig. 1.

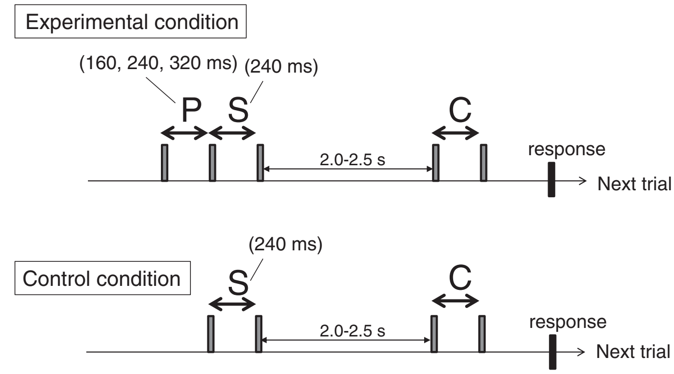

Fig. 1. Stimulus presentation chart for the experiment. The durations of preceding (P), standard (S), and comparison (C) intervals correspond to the temporal distance between the beginning of one marker and the beginning of the subsequent marker.

In the experimental condition, the standard pattern consisted of three successive stimuli, the first and the second marking the preceding time interval (P), and the second and the third marking the standard time interval (S). In the control condition, the standard pattern consisted of two successive stimuli marking S. In both cases, the comparison interval (C) was marked by two successive stimuli.

The intervals (P, S, and C) were manipulated in terms of duration between the onsets of the preceding and of the following markers, i.e., they were inter-onset intervals. S was fixed at 240 ms, and P was 160, 240, or 320 ms. The condition /160/240/ (slashes denote short tactile markers delimiting P and S, as /P/S/) was the temporal pattern in which considerable underestimation occurred in both the auditory and the visual modality (Arao et al., 2000; Nakajima et al., 2004). The number of conditions was 4 (3 P-durations + 1 control). The duration of C was 100, 140, 180, 220, 260, 300, 340, or 380 ms.

Stimulus presentations were controlled with a computer application (E-prime; ©Psychology Software Tools) installed in a computer (IBM Netvista). Each marker was presented to the right hand by producing electricity between two poles, positive and negative, that were attached to the back of the hand: one pole was attached between the index and the middle fingers, and the other between the ring and the little fingers.

2.3. Procedure

The method of constant stimuli was used. Participants were instructed to judge whether C was subjectively “shorter” or “longer” than S. They could respond that they were “unsure” of the relative durations of these intervals, but they were instructed not to use this alternative except when definitely necessary. Responses were made by pressing a button with the left hand.

The second pulse of S and the first pulse of C were separated with an inter-stimulus interval which randomly changed between 2000 and 2500 ms. The next trial started about 2 s after the participant's response. Each condition was assigned to one of four experimental sessions: one for /160/240/, one for /240/240/, one for /320/240/, and one for the control condition. Each session consisted of three blocks. In each block, eight C-durations were presented 10 times each, in a random order; therefore, each C-duration was presented 30 times in total through each session. Each session was conducted on separate days. Participants were free to take a break between blocks.

Half of the participants completed the three experimental conditions (sessions) before the control condition whereas the other half completed the control condition before the three experimental conditions. The order of the three experimental conditions was counterbalanced (there were 6 possible orders). Thus, there were 12 possible orders: 6 for the experimental conditions × 2 for the order of experimental and control sessions.

[1] Data of fifteen participants (10 females and 5 males) were collected for this experiment. However, we could not include the data of 3 participants (1 female and 2 males) in our results because the number of “longer” responses did not increase even when the comparison (C) duration increased physically, and we could not obtain psychometric functions from their responses. The R^2 values, which show the goodness of fit of the cumulative normal distribution curves fitted to the psychometric functions, were very low for these participants: the mean R^2 values of the four conditions for these three participants were 0.17 (SD = 0.10), 0.09 (SD = 0.13), and 0.39 (SD = 0.30), whereas the R^2 values for the other 12 participants were always higher than 0.93 (mean = 0.98, SD = 0.02).

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