Vision Research 123 (2016) 56–62

Contents lists available at ScienceDirect

Vision Research

journal homepage: www.elsevier.com/locate/visres

Effect of motion coherence on time perception relates to perceived speed

Kentaro Yamamoto [a,b,c,*], Kayo Miura [d]

[a] Research Center for Advanced Science and Technology, The University of Tokyo, Tokyo, Japan
[b] Faculty of Science and Engineering, Waseda University, Tokyo, Japan
[c] Japan Society for the Promotion of Science, Japan
[d] Faculty of Human-Environment Studies, Kyushu University, Japan

ARTICLE INFO

Article history:
Received 12 June 2015
Received in revised form 3 November 2015
Accepted 5 November 2015
Available online 29 January 2016

Keywords:
Global motion processing
Time perception
Coherence
Temporal bisection
Perceived speed

ABSTRACT

The present study examined the effect of coherence of moving visual objects on time perception. Participants observed stimuli composed of four line segments moving behind or in front of occluders. The line segments appeared to move either coherently as a diamond outline or incoherently, depending on the occlusion. Results from the temporal bisection task indicated that the duration of the coherently moving stimulus was perceived longer or shorter compared to the duration of the incoherently moving stimulus depending on the stimulus configurations. The speed comparison task revealed that the trend of the difference in perceived speed between the coherent and incoherent motions in each stimulus configuration was consistent with that of the difference in perceived duration between them. These results demonstrate the effect of motion coherence on perceived duration, and that this effect may be mediated by changes in perceived speed. Our finding provides evidence supporting the involvement of global motion processing in time perception.

1. Introduction

Time perception refers to the ability to estimate the duration and timing of events. This ability is crucial for the fulfillment of various activities (Buhusi & Meck, 2005) and for coping with a dynamic environment. In particular, temporal processing within the range of tens to hundreds of milliseconds is critical for sensory processing and motor control (Mauk & Buonomano, 2004). While temporal processing is essential to our daily lives, time perception is susceptible to non-temporal processing and duration judgment is often distorted (Fraisse, 1984). Previous studies have revealed an interesting relationship between the stimulus intensity and the perceived duration of stimulus presentation. Specifically, the perceived duration of stimuli is longer as their size (Ono & Kawahara, 2007; Thomas & Cantor, 1975), number (Mo, 1975; Xuan, Zhang, He, & Chen, 2007), or luminance (Matthews, Stewart, & Wearden, 2011; Xuan et al., 2007) increases. These findings suggest that temporal processing is associated with non-temporal processing, though the critical stage is highly controversial.

Visual motion processing is also known to influence time perception. Previous studies have shown that the perceived duration of moving stimuli is longer than that of stationary stimuli, and perceived duration increases with speed (or temporal frequency) (Beckmann & Young, 2009; Brown, 1995; Kanai, Paffen, Hogendoorn, & Verstraten, 2006; Kaneko & Murakami, 2009; Yamamoto & Miura, 2012a). These results suggest that motion-processing areas are involved in temporal processing. It is generally accepted that visual motion is hierarchically processed in multiple stages in the dorsal pathway, and different stages contribute to the processing of local and global motion information (Adelson & Movshon, 1982; Amano, Edwards, Badcock, & Nishida, 2009; Movshon, Adelson, Gizzi, & Newsome, 1985; Snowden & Verstraten, 1999). Based on this, Kanai et al. (2006) manipulated speed and motion coherence of random dots independently to examine whether global motion information plays a role in time perception. Their experiment only indicated a speed-related effect with motion coherence showing no influence on perceived duration. This suggests that early motion processing stages, which are specialized for local motion processing, are critical for motion-induced time distortion. In contrast, more recent studies have suggested the importance of later motion processing stages on motion-induced time distortion (Au, Ono, & Watanabe, 2012; Kaneko & Murakami, 2009; Yamamoto & Miura, 2012a). For example, Yamamoto and Miura (2012a) used plaid pattern motion composed of two drifting gratings with differing orientations. They found that manipulating the pattern's coherent global motion

* Corresponding author at: Faculty of Science and Engineering, Waseda University, 3-4-1 Okubo, Shinjuku-ku, Tokyo 169-8555, Japan.
E-mail address: yamamoto.kntr@gmail.com (K. Yamamoto).

http://dx.doi.org/10.1016/j.visres.2015.11.004
0042-6989/

speed influenced perceived duration. Their results suggest that motion information is involved in time perception after the process of motion integration.

Although both of the aforementioned studies (Kanai et al. (2006) and Yamamoto and Miura (2012a)) focused on the relationship between global motion processing and time perception, the conclusions were not consistent between them. One possible reason for this discrepancy is that the influence of motion coherence was diminished by changes in the other features (e.g., dot proximity or direction distribution) of the random-dot pattern used in Kanai et al. (2006). If this is the case, the effect of motion coherence should be analyzed using more controlled stimulus configurations. Another possibility is that different motion components included in the plaid pattern contributed to the influence of global motion observed in Yamamoto and Miura (2012a). The plaid pattern is composed of spatially overlapped gratings and contains second-order motion components, which were suggested to influence plaid motion perception (Cox & Derrington, 1994; Nishida, 2011; Wilson, Ferrera, & Yo, 1992; Wilson & Kim, 1994). If the duration distortion was caused by the additional motion components, it should not have an effect when the coherent stimulus does not include spatial overlap of local motion signals.

To address the above uncertainty, our study examined whether the coherence of spatially segregated moving objects influences perceived duration. To achieve this, we used a translating diamond stimulus (Lorenceau & Shiffrar, 1992; McDermott, Weiss, & Adelson, 2001; Murray, Kersten, Olshausen, Schrater, & Woods, 2002) where a diamond outline translates along a circular trajectory with its corners occluded. Although the diamond outline is partially occluded and is thus separated into four line segments, the stimulus is generally perceived as a diamond translating behind the occluders. However, if the occluders are blended into the background and become invisible, the four line segments are perceived to move incoherently in directions orthogonal to their orientation. This is because the motion of the line segments is ambiguous as a result of the aperture problem. Perceptual completion of the diamond outline behind the visible occluders can solve this ambiguity (McDermott et al., 2001).

The present study used a similar stimulus composed of four line segments located behind or in front of visible occluders to eliminate the effect of occluder visibility on perceived time. Fig. 1 shows examples of the stimulus displays. Although the line segments physically move in directions orthogonal to their orientation, the stimulus is generally perceived as a diamond translating along a circular trajectory when the corners are behind the occluders (Fig. 1A). Conversely, the stimulus is perceived as four moving line segments if completion is prevented by the inversion of the overlapping order (Fig. 1B). We used these stimuli because they do not have spatial overlap of local motion signals, and there is little difference in low-level visual features between the coherent and incoherent stimuli.

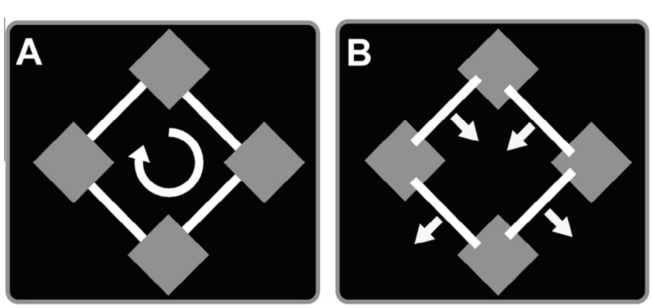

Fig. 1. Schematic illustration of the (A) coherent and (B) incoherent stimuli used in Experiment 1. The arrows represent the perceived motion direction of the stimuli.

We first compared the perceived duration of the coherent and incoherent stimuli using two different stimulus configurations, and then performed a speed discrimination task to assess whether the difference in perceived duration can be attributed to the difference in perceived speed. The perceived duration of stimulus presentation was measured using the temporal bisection task (Gil & Droit-Volet, 2009; Wearden, 1996; Yamamoto & Miura, 2012b). In this task, participants were initially trained to correctly categorize two standard durations as "short" or "long" (0.4 and 1.0 s, respectively). The coherent and incoherent stimuli were then presented with seven probe durations. Participants were asked to judge whether the duration of each stimulus was more similar to the long or short standard duration.

2. Experiment 1

2.1. Methods

2.1.1. Participants

Twelve paid volunteers (4 men and 8 women, age: 20.8 ± 1.4 years) participated in the experiment. One of them was excluded from the data because of poor performance (i.e., Weber ratio of above 0.2). All participants had normal or corrected-to-normal vision and were naive to the purpose of the experiment. All provided written informed consent. This study was carried out in accordance with the Code of Ethics of the World Medical Association (Declaration of Helsinki).

2.1.2. Apparatus

The stimuli were presented on a 22-inch gamma-corrected CRT monitor with a resolution of 1280 × 800 pixels and a refresh rate of 100 Hz, controlled by an Apple Macintosh computer. A chin rest restrained the participants' head movements at a viewing distance of 57 cm from the display. The stimuli were generated using Matlab (The MathWorks, Natick, MA, USA) with the Psychtoolbox extension (Brainard, 1997; Pelli, 1997).

2.1.3. Stimuli

The stimuli were composed of four white line segments moving behind (coherent stimulus) or in front of (incoherent stimulus) four gray occluders (3.7 deg × 3.7 deg). They were presented on a black background. The line segments (0.3 deg in width and 4.0 deg in length) were tilted at 45° to the left or right and arranged to form a virtual diamond subtending 8.5 deg × 8.5 deg. Each line segment moved sinusoidally in a direction orthogonal to its orientation within a spatial interval of 1.3 deg at a mean speed of 3.1 deg/s, whereas the virtual diamond moved along a circular path at a constant speed of 4.8 deg/s. The starting position and moving direction of the line segments were randomized in each trial.

2.1.4. Procedure

The experiment was conducted in a darkened room. Before launching the main experiment, we presented the coherent and incoherent stimuli to participants and asked them to judge whether the stimuli moved along a circular or a linear path. We confirmed that all participants correctly judged the motion direction of each stimulus. This means that the coherent and incoherent stimuli were indeed perceived as moving coherently and incoherently, respectively.

The experiment consisted of two phases, a training phase and a test phase. In the training phase, only the occluders were presented in the center of the display with two standard durations (0.4 or 1.0 s) after a 1-s central fixation. The fixation was continuously present during the stimulus presentation. Participants were asked to categorize the durations as "long" or "short" by pressing the "d"