Vertical motion triggers bouncing perception in retinotopic and body-centered spaces

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Running head: Stream/bounce perception and motion path

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Abstract

When two identical objects travel toward each other, overlap completely, and continue on toward opposite ends of a space, observers perceive them as streaming through or bouncing off each other (stream/bounce perception). In this phenomenon, proportion of perceiving bouncing increases as motion path becomes more vertical (Gobara & Yamada, submitted). However, it remains unclear whether this effect is based on the motion path defined by retinotopic or body-centered coordinates. In this study, we investigated this issue by observers tilting their head. In the experiment, the motion path of two black discs were manipulated from horizontal to vertical. Observers tilted their head 30° left or right using a head rest while they viewed display, and were asked to judge whether the two moving objects streamed through or bounced off each other. The results indicated that the peak of a psychometric function fitted to the rate of bouncing perception significantly shifted toward the direction of the head tilt. These results suggest that the effect of verticality of the motion path on stream/bounce perception is based on retinotopic coordinate.

Keywords: stream/bounce perception, motion path, oblique effect, retinotopy

When two identical objects at both sides of a space travel toward each other, overlap completely, and pass to the opposite sides, observers perceive the visual event as streaming through or bouncing off each other (stream/bounce perception: Metzger, 1934). Tons of previous studies on this phenomenon have been conducted and they found that the "streaming" event is generally dominant (e.g., Bertenthal, Banton, & Bradbury, 1993). Moreover, several features of the objects influence the stream/bounce bistable perception. For example, the streaming perception becomes dominant when the orientation of moving Gabor patches aligns with the motion axis, while bouncing perception becomes dominant when the orientation is more vertical (Kawabe & Miura, 2006). The findings suggest that orientation processing is a key to (dis)ambiguating the motion event.

Moreover, the orientation of the motion path can affect the stream/bounce perception. Gobara and Yamada (submitted) investigated that the effect of the orientation of the motion path by manipulating the orientations from horizontal to vertical, and found that the proportion of perceiving bouncing increased as the motion path becomes more vertical. The results indicated that a vertical component of the motion vector is used for judgment of the motion event in stream/bounce perception.

However, it remains unclear whether the orientation is retinotopic. In the brain, visual environment is represented by various spatial coordinates. For example, retinotopic

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coordinate defines its origin as fovea, and body-centered coordinate defines its origin as body axis. When observers tilted their own heads (i.e., when the gap between retinotopic and body-centered coordinates exists), the perceived form of figures are affected (e.g., Rock & Leaman, 1963). Thus, we hypothesized that perceived motion events are also affected by observer's head tilt: The effect of the motion path orientation on stream/bounce perception might be different between retinotopic and body-centered coordinates. Here, we investigated this issue by a simple experiment where observer's head was tilted. If the verticality of the motion path in retinotopic coordinate affected stream/bounce perception, the peak of the effect of verticality would shift in the direction of the head tilt.

Method

Participants. Sixteen participants (6 males and 10 females, M = 23.31 years) with normal or corrected-to-normal vision participated in the experiment. The present study was conducted after receiving approval from the ethical committees of Kyushu University (Approval Number: 2016-013). The written informed consent was obtained from all participants. Participation was voluntary, and participants had the right to withdraw from the experiments at any time without providing a reason.

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Apparatus. The experiment was implemented with Matlab (Mathworks; Natick, MA) using the Psychophysics Toolbox extensions (Brainand, 1997; Pelli, 1997). The software was running on Mac Pro computer connected to a 22-in. CRT monitor (Mitsubishi, RDF221S) with a resolution of 1024 × 768 pixels. The refresh rate was 100 Hz. To fix participants' head orthogonally, we used a head rest which tilted 30° left or right.

Stimuli. The moving objects were two identical black discs. Their diameters were 1.00º, and presented on a gray square (14.20º × 14.20º) placed in the center of a black background. The discs' motion started at the beginning of each trial from the both ends of an invisible horizontal line bisecting the screen, 15°, 30°, 45°, 60°, 75°, 90° (i.e., vertical), 105°, 120°, 135°, 150°, 165°, and 180° (i.e., horizontal) rotated in a clockwise direction. The initial distance between the discs was 12.21°. They moved toward opposite side with uniform rectilinear motion (6.21 deg/s) and coincided completely at the center of the square. They stopped moving and then disappeared at the other disc's starting point. The duration of their motion was 1989 ms.

Procedure. Participants viewed the display binocularly from a distance of 60 cm. The half of participants were tilted their head 30º left and the others' head was tilted 30º right. Before the trials, an experimental instruction and five practice trials were performed. By pressing the space key, each trial started. First, the fixation point was presented 1000 ms at the center of the screen, and two black discs appeared 500 ms after the onset of the fixation. Five hundred milliseconds after the onset of the discs, the fixation point disappeared and the discs began moving toward each other, eventually overlapping at the center and then continuing to move to the opposite sides of the screen, after which they vanished. Then, participants were asked to judge whether the discs streamed through or bounced off each other. There were 20 repetitions for each of the 12 conditions and the order of trials was randomized. Therefore, 240 experimental trials were conducted.

Results

To see the effect of the head tilt, we merged the data from observers who participated in the left-tilt condition into the data from ones in the right-tilt condition (Figure 1). We fitted a Gaussian function to the mean rates of bouncing perception in each of the path conditions (R^2 = .75). The Shapiro-Wilk test suggested that the data did not significantly deviate from a normal distribution (p = .20). The estimated mean of the Gaussian function was 101.7° and its 95% confidence interval was from 90.72° to 114.2°, indicating that the peak of the function was significantly larger than 90°.

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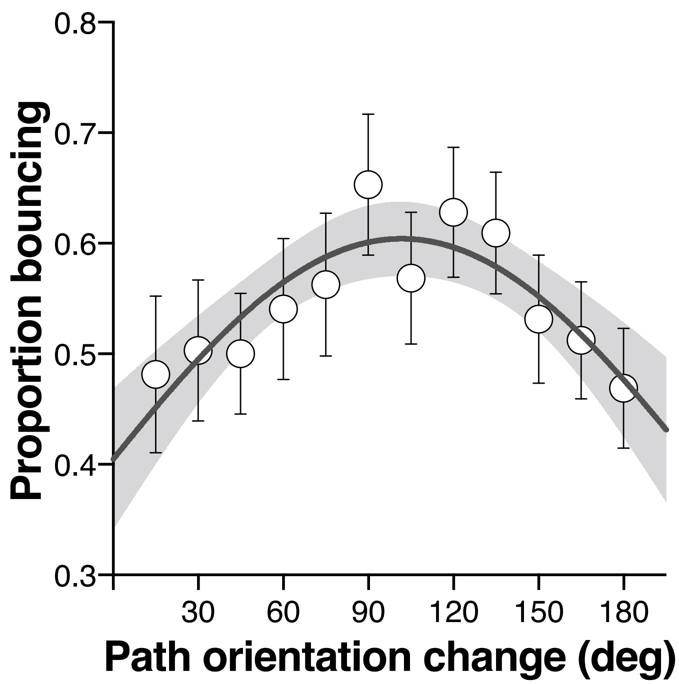

Figure 1. Results of the experiment. The thick curve represents the psychometric function fitted to the data. The gray area represents 95% confidence band. Error bars denote SEM.

Discussion

Consistent with Gobara and Yamada (submitted), the results clearly indicate that the orientation of the motion path affects stream/bounce perception. The orientation around 90° induced a higher rate of bouncing perception. More importantly, when observer's head was tilted 30°, the peak of the proportion bouncing significantly shifted toward larger values of the path orientation change. In the situation where observer's head was tilted, retinotopic coordinate was also tilted in the same direction. Therefore, the results suggested that the effect of verticality of the motion path on stream/bounce perception is based on retinotopic coordinate, rather than body-centered coordinate.

The present study has limitations. First, although a significant peak shift occurred due to the head tilt, bouncing perception was still the strongest in the 90° condition. Therefore, we cannot say that there was no influence of the body-centered coordinate system. Even if there is any influence of the body-centered coordinate system, the difference in contribution ratio of the two coordinate systems is unclear. Second, we manipulated the tilt of retinotopic coordinate by using a head rest. As a result, the head of the observer was tilted. Hence, there is a possibility that sensorimotor information of the head tilt interacted with the body-centered coordinate system and weakened the influence of the body-centered coordinate on the stream/bounce perception. Future studies can deal with this issue by conducting experiments where the observer sees stimuli in a lying position. Otherwise, this issue would be examined by experiments under conditions without constraints of gravity. Body-centered coordinate system aligns with the direction of gravity vector. If observers adapted to a microgravity environment, the peak shift of bouncing perception would increase because the body-centered coordinate system can no longer adjust the motion orientation processing, resulting in the full retinotopic processing.

Declaration of Conflicting Interests

The authors declare no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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