Naive physics alters time-to-passage judgments

Yuki Yamada, Mai Yamaguchi, and Kayo Miura

**Faculty of Human-Environment Studies, Kyushu University, 6-19-1, Hakozaki, Higashi ward, Fukuoka, 8128581, Japan*

E-mail: yy@psycho.hes.kyushu-u.ac.jp

In a time-to-passage (TTP) paradigm, observers were asked to estimate the time distance for a moving target to pass a pre-determined landmark. A circular target smoothly moved in a linear path and on the way, was gradually occluded by a static screen rectangle. Additionally, a luminance border parallel to the motion path was presented as a pictorial cue evoking a ground surface. Since the motion path was oblique (+45 or -45 deg) or horizontal, the target appeared as if it descended, ascended or translated on the ground. As a result, when the target always contacted the solid line, TTP was significantly shorter in the descending condition than in the ascending condition. On the other hand, when the target was slightly away from the border, no significant effect of the slope of the motion path on the TTP was obtained. The results showed that different motion impressions evoked by naive physics affected TTP judgment.

Key words: *time-to-passage, naive impetus, representational friction*

Introduction

Using the implicit knowledge about a physical law, we efficiently monitor and anticipate the dynamic visual environment. In the representational momentum (RM) study, forward displacement for a final position of a moving object seems attributable to top-down modulation based on the implicit knowledge about physical momentum, that is, naive physics (e.g., Finke, Freyd, & Shyi, 1986). Specifically, the knowledge of physical principles makes it hard to instantaneously stop target movement in mental representation as in the physical world. For example, Finke and Freyd (1985) showed that the velocity of a moving target affected the degree of forward displacement. It was also found that, when motion direction was downward, the degree of forward displacement increased as the size of the target increased (representational gravitational attraction, Hubbard, 1990). Moreover, forward displacement decreased when the target moved while touching the surface of a ground-like object (representational friction, Hubbard, 1995). Likewise, forward displacement decreased when a horizontally moving target burst through a vertically oriented barrier (Hubbard, 1995). In this way, our cognitive system appears to internalize naive physics and exploit it when interpreting dynamic changes in the outer world.

Here we try to confirm the effect of naive physics on time-to-passage (TTP) judgment. TTP is an estimated time distance that a target travels from one end to the other end of the object (or surface) occluding the target: In this paradigm the target movement behind the occluder should be mentally anticipated without retinal stimulation. In the present study, a pictorial cue, which described three kinds of slope of a ground, was employed to introduce the descending, ascending, or translating movement of the target. If the target appears to descend down the slope, its velocity impression will seem to accelerate. Hence we predict that TTP will be shorter in the descending condition than in the ascending condition.

Experiment 1

Methods

Observers: Fourteen naive undergraduate students participated in this experiment.

Apparatus and Stimuli: Figure 1 shows the stimuli used in Experiment 1. Stimuli were displayed on a CRT monitor with 1024 × 768 pixels resolution and a 75 Hz vertical refresh rate at the viewing distance of 60 cm. A PC/AT compatible computer was used to control presentation of stimuli and collection of data. A white-filled circle with a radius of 12.7° of the visual angle was presented on the black background as a stimulus presentation field. A fixation cross was at the centre of the field. The black background and the white presentation field were always presented. The target stimulus was a small black circle with a radius of 0.3°. As an occluder, a light-grey rectangle with a height and widths of 25° and 5° or 10°, respectively was overlaid with whole stimuli but the fixation so as to go across the center of the stimulus presentation field. In the cued condition, a luminance border (or edge), which separating the stimulus presentation field into white and gray regions, was presented along the diameter of the field circle as having the impression of a ground surface. However, in the uncued condition, they were not presented. The target smoothly moved from right to left and vice versa with the distance of 6.7°. The speed of the target movement was 10° / sec. The orientation of the path of the target movement as well as the luminance border was 0 deg, 45 deg, and -45 deg. In the cued condition, the target always touched the luminance border and was gradually going behind the occluder.

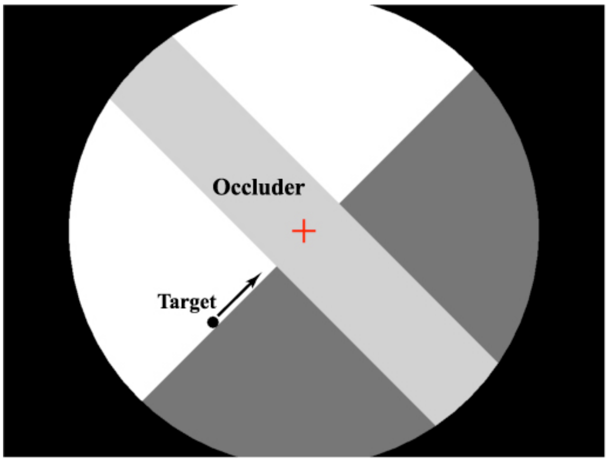

Figure 1. Schematic representation of stimuli in Experiment 1. This figure represents an example of 5° WIDTH condition. The target circle smoothly moved towards the centre. Note that the arrow and labels in this figure were not presented in the experimental trial.

Procedure: The experiment was conducted in the dark-room. The visual distance was 60 cm. Observers were asked to maintain their gaze on the fixation cross and initiate each trial by pressing the spacebar. When the spacebar was pressed, the line (not presented in the uncued condition), the screen board, and the target appeared. The observers were instructed to press the spacebar again when the target seemed to contact the opposite side of the entered side of the occluder. A total of 240 experimental trials involving three conditions: CUE (cued and uncued), WIDTH of the screen board (5° and 10°) and SLOPE of the ground surface (translating, ascending and descending) were conducted in a pseudo-randomized order.

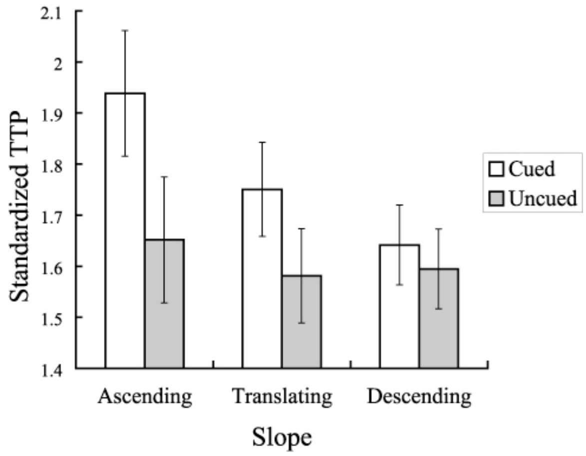

Figure 2 Standardized TTP in Experiment 1. White and grey bars show the results with the cued and uncued conditions, respectively. Error bars denote standard errors.

Results and Discussion

The time distance from the disappearance of the target to observers' reaction by spacebar was measured as produced TTP. Moreover, the standard TTP, which was obtained by dividing produced TTP by actual TTP, was analyzed (Figure 2). Three-way analysis of variance (ANOVA) of standardized TTP with CUE (cued and uncued), WIDTH (5° and 10°) and SLOPE (translating, ascending and descending) as factors showed a significant main effect of CUE [$F(1, 13) = 9.76$, $p < .01$], WIDTH [$F(1, 13) = 43.34$, $p < .001$], and SLOPE [$F(2, 26) = 15.64$, $p < .001$]. The interactions between CUE and SLOPE [$F(2, 26) = 8.00$, $p < .003$] and along CUE and WIDTH and SLOPE [$F(2, 26) = 3.61$, $p < .05$] were also significant. Simple main effect of SLOPE in the cued condition was significant [$F(2, 52) = 22.82$, $p < .001$], but not in the uncued condition [$F(2, 52) = 1.53$, *n.s.*]. Post hoc comparisons by Ryan's method indicated that the standardized TTP was significantly shorter in descending than translating and ascending conditions [$t(52) = 2.45$, $p < .02$; $t(52) = 6.68$, $p < .001$, respectively], and shorter in translating than ascending condition [$t(52) = 4.23$, $p < .001$].

In Experiment 1, TTP varied with the slope of motion only in the cued condition. This fact indicates that the modulation of TTP was based on naive physics of motion on the slope. However, a considerable difference in stimulus configurations between cued and uncued conditions might make this effect. Hence, Experiment 2 tested this issue, not evoking the impression of the slope by means of detaching the target from the luminance edge.

Experiment 2

Methods

Apparatus, stimuli, and procedure were identical to Experiment 1 except for following: the target was always detached from the line in 0.7°., Here, we no longer pursued the uncued condition and WIDTH 10° condition, and thus the luminance border was presented in every trial and the width of the screen board was always 5°). Another 13 naive observers participated in this experiment.

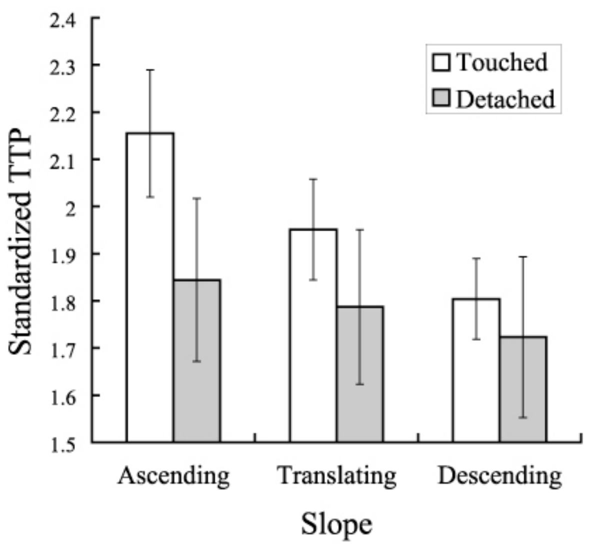

Figure 3 Standardized TTP in Experiment 2. White and grey bars show the results with the touched and detached conditions, respectively. Error bars denote standard errors.

Results and Discussion

Between-subjects comparison with the data from Experiment 1 was conducted (Figure 3). Two-way ANOVA of standardized TTP with CONTACT (touched and detached) and SLOPE (translating, ascending and descending) as factors showed a significant main effect of SLOPE [$F(2, 50) = 15.13$, $p < .001$], but not in CONTACT [$F(1, 25) = 0.85$, *n.s.*]. The interaction between them was significant [$F(2, 50) = 3.69$, $p < .04$]. Simple main effect of SLOPE in the touched condition was significant [$F(2, 50) = 16.84$, $p < .001$], but not in the detached condition [$F(2, 50) = 1.97$, *n.s.*]. Post hoc comparisons by Ryan's method indicated that the standardized TTP was shorter in descending than translating condition [$t(50) = 2.47$, $p < .02$], and was shorter in translating than ascending condition [$t(50) = 3.42$, $p < .002$].

Experiment 2 clearly showed that the TTP modulation effect was not attributable to the difference in the stimulus configuration between cued and uncued condition in Experiment 1. Preferably, the effect seemed derived from the difference in velocity impression in the moving target.

General Discussion

The present study was aimed to test the effect of the orientation of motion path and the existence of the ground-like border on TTP judgments. It showed that TTP was modulated by those factors. This indicates that the variety of velocity impression with three kinds of slope of the ground-like border. Since the impression of motion would be accelerated or decelerated by the slope, TTP was modulated (David, 1975). Moreover, the modulation was diminished when the cue could not express the ground surface.

In the RM paradigm, Yamada, Kawabe, and Miura (2005) demonstrated that a smoothly moving target with forward spin resulted in a larger degree of forward displacement than that with backward spin. They suggested that the spin direction may alter the target's velocity impression, namely, forward spin evokes higher speed motion than backward spin Therefore, given the outcome from this study, the similar effect might be here obtained in the TTP judgment.

References

David, A. R. (1975). Perception and Extrapolation on velocity and acceleration. *Journal of Experimental Psychology: Human Perception and Performance*, **1**, 395-403

Finke, R. A. & Freyd, J. J. (1985). Transformations of visual memory induced by implied motions of pattern elements. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, **11**, 780-794.

Freyd, J. J. & Finke, R. A. (1984). Representational momentum. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, **10**, 126-132.

Hubbard, T. L. (1990). Cognitive representation of linear motion: possible direction and gravity effects in judged displacement. *Memory & Cognition*, **18**, 299-309.

Hubbard, T. L. (1995). Cognitive representation of motion: evidence for friction and gravity analogues. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, **21**, 241-254.

Yamada, Y., Kawabe, T., & Miura, K. (2005). Spin-orbit coupling in vision: Evidence from representational displacement. *Journal of Vision*, 5(8), 658a, http://journalofvision.org/5/8/658/, doi:10.1167/5.8.658.