Human Anticipation Property of Free-falling Object Position in Virtual Environment

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Abstract: Human anticipation property of a free-falling object was experimentally studied by using a VR system, and the obtained results were compared to the results in real environment. Participants were required to anticipate the position of a free-falling virtual ball when a visual stimulus was given at a specific interval of the ball disappearance. The anticipated position of the ball changed lower proportionally to the interval, while the interval was varied from 30 to 190ms. The slopes of the regression lines represent an estimate of the velocity, i.e. "the anticipated velocity" which the subjects might utilize for the ball position anticipation. The anticipated velocities were approximately five times smaller than the actual velocities. This unexpected slowdown was independent from the distance in virtual space. Therefore, this slowdown appears to be caused by the internal process of recognition and anticipation rather than physical limitations such as eye movement velocities.

Key Words: *Position anticipation, Free-falling object, Virtual environment*

1. INTRODUCTION

Catching or interception of a free-falling object is an important skill in sports such as baseball, badminton, etc. It is a difficult task and requires well-trained skill. It is expected that the analysis of perception, anticipation and motor control property related to the moving object interception could reveal the reason why interception tasks are so difficult.

Performance in moving object hitting or catching tasks, which requires anticipation, has been studied [1, 2]. The studies focused on the property of entire process that includes perception, anticipation and motor control. However, in order to reveal the mechanism of moving object interception and the cause of failure, it is required to estimate the anticipation property of a moving object, excluding the motor control property.

A number of studies have been carried out on perception and anticipation of moving objects in psychology (e.g. representational momentum; RM [3], launching event; LE [4] and time-to-contact; TTC [5]). With respect to the research on TTC, there are several reports about underestimation of TTC; however, the causes of the underestimation have not been clarified. A number of other questions still remain on the anticipation mechanism of moving objects.

This study focused on the experimental analysis of anticipation property of a free-falling object excluding motor control property. A virtual reality experimental system was developed in order to analyze the anticipation property of a free-falling object position after disappearance of the object. In typical TTC tasks, subjects judge the time using information about distances between an object and a particular point. The task in this study was to answer the anticipated position at visual stimulus onset. It is a time-to-position anticipation task, which is opposite to TTC task. This paper is to report the unexpected anticipation property in that task.

2. METHODS

2.1 Subjects

Twenty-four students, 19-21 years old with normal or corrected-to-normal vision, participated in the experiment. Twelve subjects participated in the experiments for a free-falling object and twelve in those for a falling object at a constant velocity.

2.2 Anticipation of free-falling object

2.2.1 Experimental set-up

The experimental system consisted of a personal computer and a flat CRT display (22 inches). The real-time graphic software for representation of a falling objcet was developed using OpenGL library. Both the graphical rendering frequency and the monitor refresh rate were set at 100 frames/s. The distance between the subject's eyes and the display was 25cm and the height of the eyes was 120cm. The viewing angle in the setup was 60 degrees. The subjects' chin and forehead were fixed with a fixing apparatus to prevent the head from

moving.

In order to examine the observed phenomena in real environment, a ball launching machine, ball position detectors and a board (height 1.2m) with LEDs were manufactured to perform a similar experiment in real space.

2.2.2 Visual stimuli

In the virtual room represented in the display, a ping-pong ball was vertically launched from behind a board with a height 1.1m. The ball fell freely from 1.67m in height and disappeared behind the board. A visual stimulus, a color change of the surface of the board that simulates the illumination, was applied after a specific interval of the ball's disappearance. The interval was varied among 30, 80, 120, 160 and 190ms randomly. The ball's position at each sitimulus onset was 10, 25, 40, 55 and 70cm from the top of the board. The changed color of the board remained until the subject finishes each anticipation task.

2.2.3 Procedure

The subjects were requested to sit in front of the display with their head fixed with an apparatus as shown in Fig.1. They were required to observe the motion of a free-falling ping-pong ball and to project the anticipated ball position at visual stimulus was presented. The subjects repoted their judgments using a 16-level scale printed on a board. Five sets of 25 trials were performed in each subject and a short break was given between the sets.

The air resistance coefficient of the ping-pong ball was set to be the same as the actual ball. The velocity of the virtual ball at its disappearance was 3m/s.

In order to investigate the influence of eye movement velocities, the subjects performed the same tasks at three different ball-to-eye distances of 2.5m, 3.5m and 4.5m in the virtual environment. The displayed visual images were non-stereoscopic to prevent the subjects' eyestrain. Therefore, the distance from the subject to the ball and to the board were chosen as almost the same, to allow the subjects to anticipate the ball position without recognizing the distance correctly. The experiment in each set condition was carried out on a different day to avoid the effect of fatigue.

2.3 Anticipation of moving object at constant velocity

The subjects were also required to perform the position anticipation task of a moving object at constant velocities. The experimental apparatus and set-up were the same as the previous experiment. Three different modes in terms of the ping-pong ball movement were used: fall at constant velocities of 1m/s, 3m/s and gravitationally accelerated free-fall. The ball fell from 2.7m high and disappeared behind the board.

2.4 Analysis

Scatter diagrams of the actual position and the anticipated position were constructed from the obtained data. The position data that each subject anticipated were transformed as distances from the top edge of the board. Least squares methods were applied to the data of these distances vs. the time of the visual stimulus presentation and regression equations were calculated. The slopes of the regression lines mean the velocities that the subjects might use to anticipate the ball position. For convenience, we call them "the anticipated velocity", and analyze.

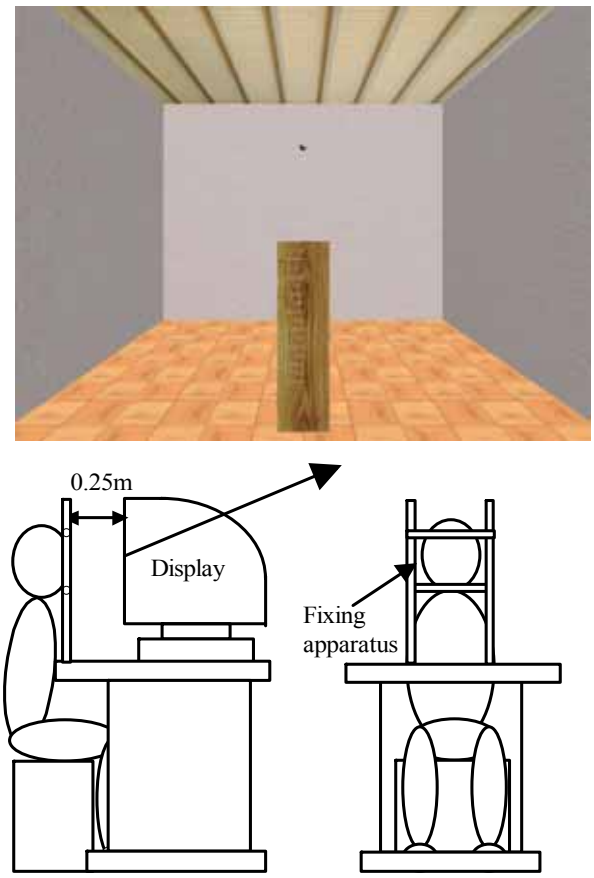

Fig.1. Experimental set-up and image in virtual environment

3. RESULTS

Fig. 2 shows a typical example of the scatter diagrams in the anticipated position as opposed to the interval that is the time of the visual stimulus presentation after the ball's disappearance. The ball-to-eye distance in virtual environment was 3.5m. The distance from the top of the board to the anticipated position increased proportionally to the interval. However, these distances were smaller than that of the actual position of the free-falling ball.

The anticipated velocities calculated by regression analyses were five times less than the actual velocities. The trends in 2.5m and 4.5m conditions were similar to the presented 3.5m results.

Fig. 3 shows comparison of the means and the standard deviations of the anticipated velocities calculated from regression lines of twelve subjects. In spite of the ball-to-eye distances in all distance conditions, the anticipated velocities were five times less than the actual ball velocity at the ball's disappearance (3m/s). The experimental results in real space are also shown in Fig. 3. The trends in real environment are the same. Both results suggest no relation between the eye movement velocity, which differs according to distance, and the anticipated velocity.

Fig. 4 shows comparison of the means and the standard deviations of the anticipated velocities calculated from regression lines in the constant velocity experiment. The ball-to-eye distance was 3.5m in each condition. As compared to the actual velocities, the anticipated velocities were four times less under the 1m/s constant velocity condition, and six times less under the 3m/s constant velocity condition and free-fall condition. The anticipated velocity under the 3m/s was equal to the one under the free-fall. Therefore, it was confirmed that the anticipated velocity is remarkably smaller than the actual velocity and that the motion properties of falling objects such as velocity and acceleration have no strong effect on the extent of slowdown in the anticipated velocity.

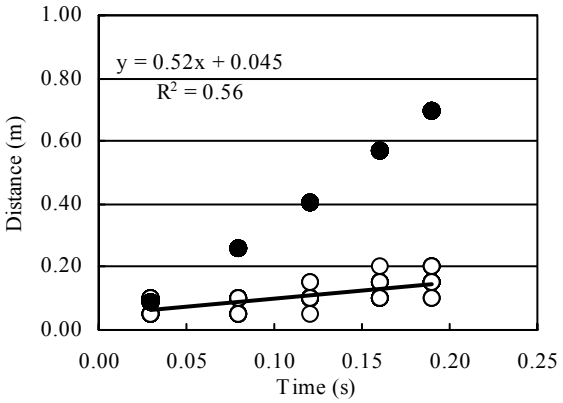

Fig. 2. The anticipated position and the interval the ball-to-eye distance of 3.5m in the virtual environment (○anticipated, ●actual):
Distance means the downward distance from the top of the board to the anticipated position and from the top of the board to the actual one.

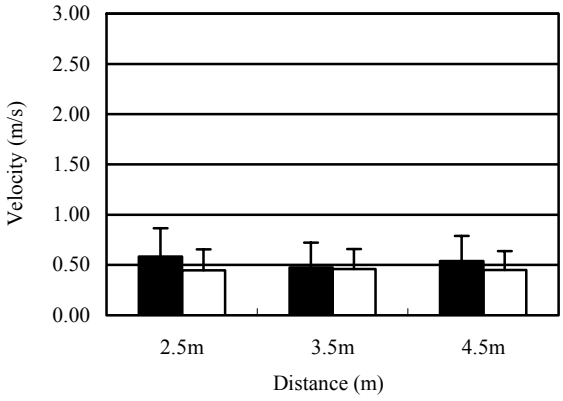

Fig. 3. The anticipated velocity calculated by regression analysis in the ball-to-eye distance in virtual and real environment (■virtual, □real)

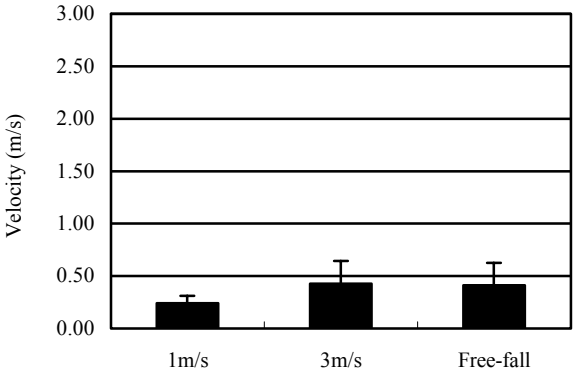

Fig. 4. The anticipated velocity calculated by regression analysis in each of the three modes of ball motion

4. DISCUSSION

The anticipated velocities were significantly smaller than the actual velocities in the free-falling object anticipation tasks. It was speculated that acceleration might influence anticipated velocity. However, anticipated velocity under the 3m/s constant velocity condition was almost equal to that of the free-fall condition. The anticipated velocity under the 1m/s condition was also significantly smaller than the actual one. These results nullified the possibility that the acceleration influenced the anticipated velocity. Therefore, it appears that the cause of the small anticipation velocity could be due to anticipation mechanism rather than velocity perception property of a moving object.

Regarding perception of colliding objects, it is known as launching event that the moving velocity before the

collision is perceived to be slower than the actual velocity if the velocity of the collided objects is slower after the collision [4]. The slowdown of the anticipated velocity in this study could be reasoned to be that the subjects might perceive the disappearance of the ball as a collision with the board. However, the anticipated velocity is obviously not zero. Although such a question remained, psychological collision is one of the promising hypotheses on the slowdown of the anticipated velocity.

In previous studies on TTC, subjects were required to anticipate the collision time while a distance to a collision point was given. The task used in this study was to anticipate the object position while a time was given by a visual stimulus. It is the inverse task of the conventional TTC task. The observed slowdown could also be explained by inexperience with this inverse task.

5. CONCLUSIONS

The position anticipation task of a free-falling object disappearing behind a board was performed in a virtual environment. The anticipated velocity was five times smaller than the actual velocity. The result had no relation to eye movement velocity and acceleration. The reason of the observed slowdown has been hypothesized as psychological collision or inexperience with the task. Further studies are needed to clarify the reasons for the results.

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