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Effect of the Horizontal Visual Field on Human Sense of Direction in a Curved Passage

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ABSTRACT

The purpose of this study was to investigate the effect of the horizontal visual field on the accuracy of the sense of direction in the curved passage. Ten college students participated in the experiment. The subjects were asked to wear a head-mounted display with a visual field of about 180 degrees (StarVR One/ StarVR Corporation) and to hold a controller. They were then asked to walk through some curved passages constructed in a virtual environment. First, a virtual arrow was displayed and placed at the starting point of the passage. Subjects were asked to memorize the direction indicated by the virtual arrow (instructed direction). After memorization, the subjects were asked to walk to the end of the passage. When the subjects reached the end of the passage, the entire passage was removed, and only an arrow indicating the direction of travel at the end of the passage appeared. After the arrow appeared, subjects changed the direction of the arrow with the controller to reproduce the instructed direction (reproduced direction). The angle difference between the "instructed direction" and the "reproduced direction" was used to extract the change in the sense of direction. The turning angle of the curved passage was set at six levels in 15-degree increments, ranging from 15 to 90 degrees (15, 30, 45, 60, 75, and 90 degrees). In addition, the subject's horizontal visual field was restricted to two levels (90 and 180 degrees). A total of twelve conditions were created by combining these two variables. As a result of the experiment, there was no significant difference in the difference between "instructed direction" and "reproduced direction" between the condition with the horizontal visual field of 90 degrees and 180 degrees. This result suggests that the accuracy of the sense of direction is not significantly changed even when the horizontal visual field is limited to 90 degrees. Therefore, the visual field outside of 90 degrees does not seem to affect the accuracy of direction sense in curved passage. Therefore, it is believed that the results of our previous study can be applied even when the visual field is wider than 90 degrees.

Keywords: Curved passage, Sense of direction, Virtual environment

INTRODUCTION

A sense of direction plays an important role in moving efficiently from one place to another. For example, people with a good sense of direction are better at learning routes than those without (Kato et al., 2003). People with a good sense of direction find their way more quickly and make fewer mistakes than those with a poor sense of direction (Alycia et al., 2009). There is also a positive correlation between the frequency of experiencing error behaviors such as "getting lost in an underground mall or shopping center," "passing by the wrong street to turn," and "losing sight of a friend or family member with whom you were shopping" and the self-assessment of sense of direction (Haga, 2016).

Individual differences in the sense of direction have been found to correlate with personality traits and age (David et al., 2015). In addition, women tend to rate their sense of direction lower than men (Edward et al., 2003)(Jeanne et al., 2000), and from childhood to adulthood, self-assessments decrease in women and increase in men (Donald et al., 2002). In addition, it is difficult to improve the sense of direction through training (Ishikawa et al., 2020). Therefore, in order to reduce the frequency of daily errors, it is necessary to design spaces that are less likely to shift one's sense of direction.

There are some studies examining the effect of spatial shape on the sense of direction. For example, Yamamoto et al. (2002) conducted a study on the judgment of direction in a curved passage. The subjects were asked to walk along a curved passage, and the changes in their sense of direction were examined. The experimental results showed that the turning angle of the curved passage was underestimated and that the four directional reference axes (front, back, left, and right) were used to judge the direction. Sadalla et al. (1989) measured the change in the subjects' sense of direction before and after walking through a pathway containing a single turn from 15 to 165 degrees. The results showed that the change in the sense of direction was smallest for the pathway with a 90-degree turn.

In a previous study, we also investigated the relationship between the turning angle and the radius of curvature of the curved passage and the sense of direction using a head-mounted display (Oculus Quest/Oculus) (Takahashi et al., 2023). However, the horizontal visual field of the head-mounted display used in the study was about 90 degrees, whereas the human horizontal visual field is about 200 degrees (Peter et al., 2012). And it has been demonstrated that a restricted horizontal visual field negatively affects distance judgments (William et al., 2019). Because of this, the results might be different when passing through a curved passage with a wider horizontal visual field. Therefore, in this study, the effect of the horizontal visual field on the accuracy of the sense of direction in the curved passages was investigated.

OUTLINE

Ten students (six males and four females) participated in the experiment. Curved passages with different turning angles were created using virtual environment software (Vizard7/World Viz). These passages were presented to the subjects using a head-mounted display (StarVR One/StarVR Corporation).

The subjects walked through the passages and changes in their sense of direction were examined. First, a virtual arrow was displayed at the beginning of the passage. The subjects were asked to memorize the direction indicated by the virtual arrow (instructed direction). After the subjects passed through the passage, they reproduced the instructed direction using a controller (reproduced direction). The angle difference between the "instructed direction" and the "reproduced direction" was used to extract the change in sense of direction.

There was a possibility that subjects would look around to confirm the shape of the passage they were passing and use it as a cue when reproducing the direction. To prevent this, the system was programmed to make the passage disappear when the subjects finished walking through it. In this case, it is impossible to modify the reproduced direction by referring to the shape of the passage. This would allow us to verify the effect on the sense of direction caused solely by passing through the passage, without being influenced by information obtained from the environment after passing through the passage.

CONDITIONS

The passages used in the experiment consisted of curved and straight parts. The width of the passages was 1500 mm, the height was 2500 mm, and the radius of curvature of the curved part was 3500 mm inside and 5000 mm outside. The length of the straight part was set so that the distance from the start point to the end point was 8176 mm (Fig. 1). The start and end points were set 750 mm away from each end of the passage, and spherical markers were placed on the floor. The floor, walls, and ceiling were white (Fig. 2).

The turning angle of the curved part of the passage was set at six levels in 15° increments (15°, 30°, 45°, 60°, 75°, and 90°) (Fig. 3). In addition, the subject's horizontal visual field was restricted to 2 levels (90 and 180 degrees) (Fig. 4). A total of twelve conditions were set by combining these two variables. Each condition was presented twice in random order for each subject.

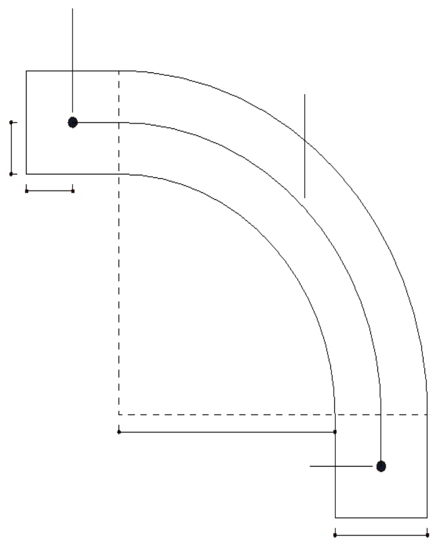

Figure 1: Dimensions of the passage.

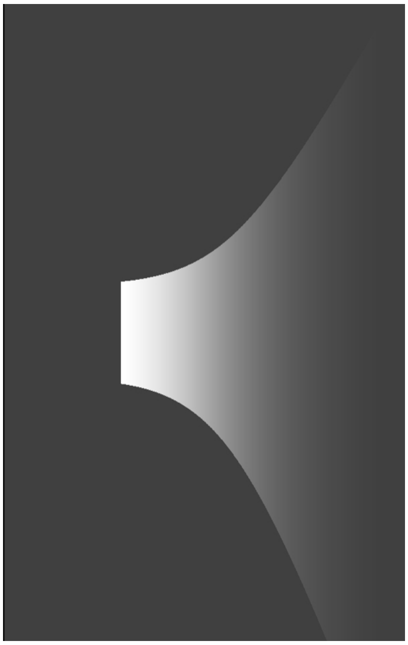

Figure 2: Inside the passage.

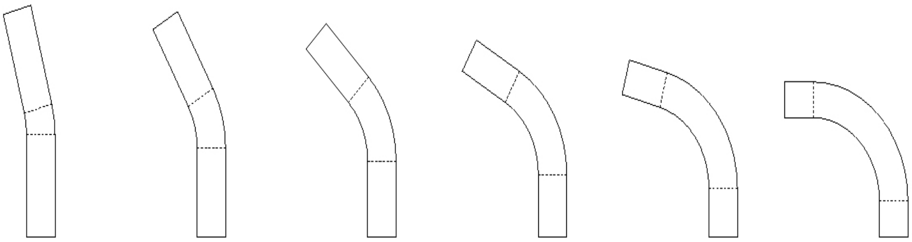

Figure 3: Turning angle conditions.

Figure 4: Horizontal visual field conditions.

The angle difference between the "instructed direction" and the "reproduced direction" was used to assess the subject's misshift of sense of direction. The "instructed direction" was presented to the subject before walking by displaying an arrow in front of the subject. The direction of the arrow is the direction of the passage at the starting point.

The "reproduced direction" was created by adjusting the arrow with the controller at hand. This arrow was displayed after the passage disappeared and was programmed to rotate in the direction the controller was pointed while the controller button was pressed. Subjects were asked to adjust the direction of the arrow to match what they thought was the "instructed direction" presented to them before walking.

PROCEDURE

First, subjects wore a head-mounted display and earmuffs and held a controller. They then practiced once. A total of 24 trials were then repeated, two for each experimental condition, using procedures (1) to (5).

1) Memorize the instructed direction at the beginning of the passage.
2) Walk to the end of the passage.
3) When the subject reaches the end of the passage, the entire passage disappears, and the arrow indicating the direction of travel at the end of the passage appears.
4) Change the direction of the arrow with the controller to reproduce the instructed direction.
5) When the reproduction of the instructed direction is complete, a spherical marker appears, indicating the location of the beginning of the next passage to be presented. The subject is asked to move to the location of the marker.

RESULTS AND DISCUSSION

The angle difference between the instructed direction and the reproduced direction was calculated, and the average of the subjects was obtained for each experimental condition (Fig. 5). An analysis of variance was performed on the difference between the instructed direction and the reproduced direction, with "turning angle of the passage" and "horizontal visual field" as factors. As a result, no interaction was confirmed, the main effect of "turning angle of the passage" was confirmed, and the main effect of "horizontal visual field" was not confirmed. Regarding "turning angle of the passage", Bonferroni's multiple comparison test revealed significant differences between several conditions.

Since no significant difference was found between the conditions of 90 degrees and 180 degrees of the horizontal visual field, it is suggested that the accuracy of the sense of direction is not significantly changed even when the horizontal visual field is limited to 90 degrees. Therefore, the visual field outside of 90 degrees does not seem to affect the accuracy of the sense of direction.

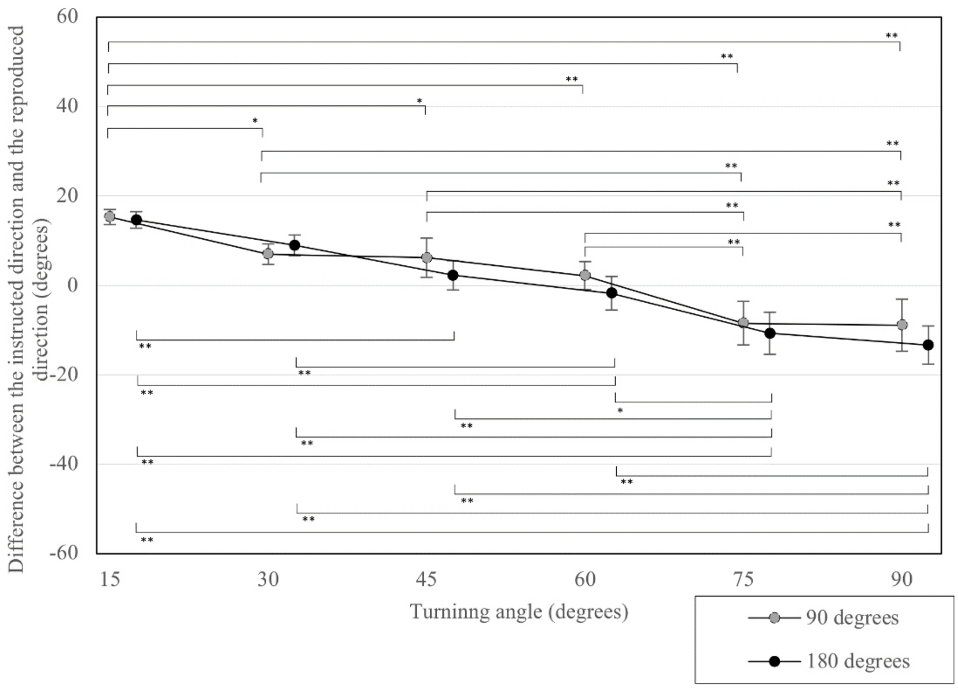

Figure 5: Difference between the instructed direction and the reproduced direction for each condition.

A positive value for the difference between the instructed and reproduced direction indicates that the reproduced direction was shifted clockwise, and a negative value indicates that the reproduced direction was shifted counterclockwise. In this experiment, because the subjects passed through a left-turning passage, when the reproduced direction was shifted clockwise, the subjects rotated the arrow more than the turning angle of the passage and overestimated the turning angle of the passage. Conversely, when the reproduced direction was shifted counterclockwise, subjects underestimated the turning angle of the passage.

From the data trend, it can be observed that when the turning angle of the passage is 60 degrees, the difference between the instructed direction and the reproduced direction is the smallest, regardless of whether the field of view is 90 degrees or 180 degrees. As the turning angle decreases, there is a tendency to overestimate the turning angle of the passage. And as the turning angle increases, there is a tendency to underestimate it. Therefore, it is conceivable that subjects use 60 degrees as a reference when reproducing the instructed direction and judge whether the turning angle of the passage they passed through is larger or smaller than 60 degrees. It is also conceivable that the difference between 60 degrees and the turning angle of the passage they passed through is perceived as smaller than the actual difference.

CONCLUSION

In this study, a subject experiment was conducted in a virtual environment using the turning angle of a curved passage and the horizontal visual field of the subject as experimental variables to verify the effect of the shape of the curved passage and the horizontal visual field on the sense of direction. The results are summarized below.

- There was no significant difference in the difference between "instructed direction" and "reproduced direction" between the condition with the horizontal visual field of 90 degrees and 180 degrees.
- The turning angle of the passage is most accurately perceived when it is 60 degrees, and when it is smaller than 60 degrees, it is perceived as larger than reality, and when it is larger than 60 degrees, it is perceived as smaller than reality.

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