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Effect of Colorfulness of Texture Arranged on Sidewall of Pathway on Walking Speed

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ABSTRACT

Controlling human walking speed is an important topic in architectural planning. Understanding the factors that cause changes in walking speed can contribute to crowd manipulation and to improving the attractiveness of streets. Visual information is one of the most important factors that can alter walking speed and has been the subject many research. However, only a few studies have examined the relationship between color visual stimuli and walking speed. Therefore, in this study, we conducted an experiment using virtual environment technology to evaluate the effect of the color of the texture of the side walls of a corridor on walking speed. The main objective of the study was to quantitatively analyze the experimental results in order to obtain knowledge useful for designing attractive streets. The results showed that the average walking speed was significantly higher umder the colored condition than the noncolored condition, especially when the gazing point was not fixed in the direction of travel. These significant differences were independent of the tile size. These results indicate that walking in the colorful environment resulted in faster walking speeds than walking in the noncolorful environment.

Keywords: Walking speed, Gazing point, Peripheral vision, Subjective experiment, Virtual reality

INTRODUCTION

Walking speed is currently being studied in a wide range of fields, including architecture, management engineering, rehabilitation medicine, and biomechanics. In terms of internal factors of pedestrians, it has been found that walking speed slows down with increasing age, and muscle weakness due to aging is said to be the main cause (Busch 2015) (Bendall MJ 1989). In terms of external factors, background music(Guang Zeng 2018), "width of walking space," "side height," "cross-sectional shape," and "road installations" were found to affect walking speed (Matsuki 2009). In terms of walking space width, it was suggested that people walk faster in narrower spaces, and in terms of emotional evaluation of the environment, walking speed was shown to be slower in places that indicated positive emotions (Franěk, M 2013). Thus, both internal and external factors are related to pedestrians' walking speed, which is also related to their impression of space. In this experiment, we will focus on vision among the external factors that can be manipulated independently of the subject, and conduct a walking speed experiment.

METHOD

Experimental Environment

The participants of the experiment, ten university students, were asked to wear a wide-field head-mounted display (Star VR one/Star VR Corporation/210° horizontal viewing angle). The actual experimental room was large enough (9.68 m x 15.6 m) to allow the participants to walk around within the virtual environment on their own feet, as the HMD was perfectly positioned within its range.

Figure 1 shows how the experiment was conducted. The participants were asked to walk 6 meters each along a corridor in eight conditions presented within this virtual environment, and their walking speed was measured. The common settings for each condition were as follows: the width of the passageway was 6 m, and the height of the side walls was 6 m on both the left and right sides. The total length of the corridor was set to 200 m so that the end of the corridor would not be visible while the participants were walking.

The texture of the side walls of the aisle was made of small square tiles joined together. Two tile sizes (500 mm square and 1000 mm square) and two tile color depths (colored and non-colored) were combined to form different experimental conditions. To each of these four conditions, we created a total of eight conditions, including one in which participants were asked to gaze at an arbitrary location and one in which they were instructed to continue gazing at a point floating 30 m away in the direction of travel. Participants examined these eight conditions in a random order.

Methods

At the beginning and end of the eight conditions, the individual subjects' walking speeds were measured in a reference space shown in Fig. 2 with white walls and no tiles. Each subject then walked through each of the eight conditions shown in Fig. 3 once and their walking speed and gaze point coordinates were recorded for each condition. The coordinates of the subject's gaze points

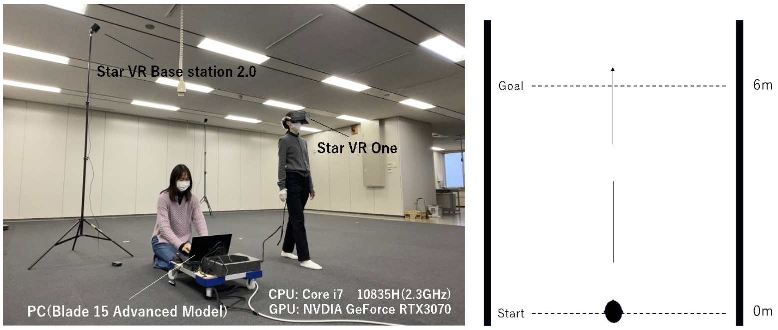

Figure 1: Experimental environment.

Figure 2: Reference space.

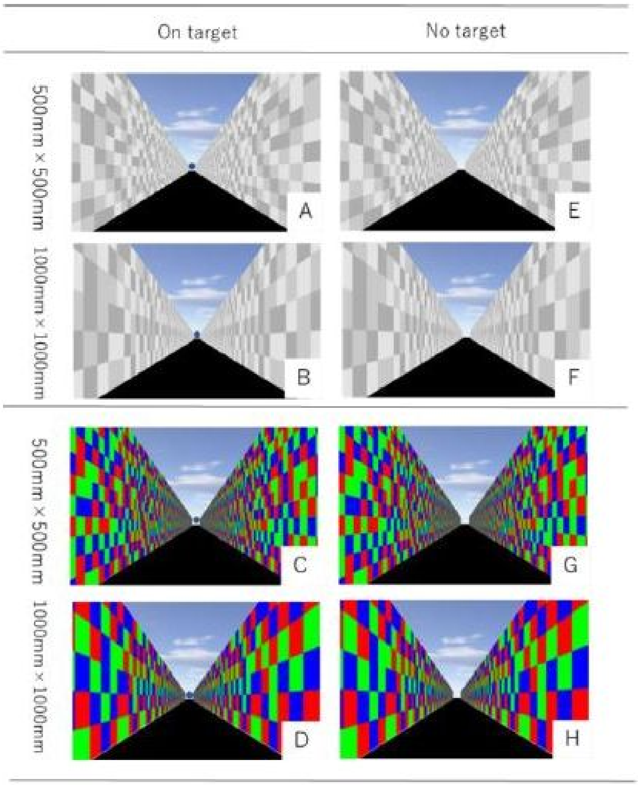

Figure 3: Experimental condition.

during the experiment were recorded by the eye movement tracker built into the head-mounted display. By analyzing these eye movements, it is believed that the subjects' gaze points during walking may affect their walking speed.

Calculation of Walking Speed

The walking speed was calculated using the subject's head coordinates obtained from the head-mounted display every 0.1 second. The depth displacement of the head coordinates was converted to velocity and the walking speed obtained under the reference conditions is referred to as the reference walking speed. In order to account for differences in walking speed among subjects, the difference between this value and the walking speed obtained under each condition is used in the analysis and compared using the following equation. This value is defined as the amount of change.

variation = walking speed for each condition − standard walking speed

When the entire measurement period is compared, the data encompasses the acceleration portion of the start of walking. In this study, 4.5 m was used for analysis, excluding 1.5 m from the start, in order to compare speeds in constant walking motion

RESULTS AND DISCUSSION

Walking Speed

An analysis of variance of the walking speed data obtained in the experiment revealed no main effects or interactions among the experimental conditions, as shown in Figure 4. Next, an analysis of variance was conducted for the factors of wall tile size, saturation, and gazing point coordinates. The results showed a simple main effect (at the 5% level) of "color" in the "no target" condition. When two of the three factors were combined to perform a multiple comparison test using the Bonferroni method (5% level), a change of 0.042 and 0.0043 was found for the 'no goal' and 'color' in Figure 5, and a large difference in the amount of change was found in the analysis using gazing point coordinates and saturation as factors. This means that significant differences in walking speed were detected in conditions E and F and conditions G and H.

Gazing Point

Condition C and Condition G show a large difference in walking speed with and without targets. These two will be compared to analyze the difference in eye movement affected by the presence or absence of a target. The ball was placed at X = 0 and the wall at X = ±3.0. Analysis of the X coordinate

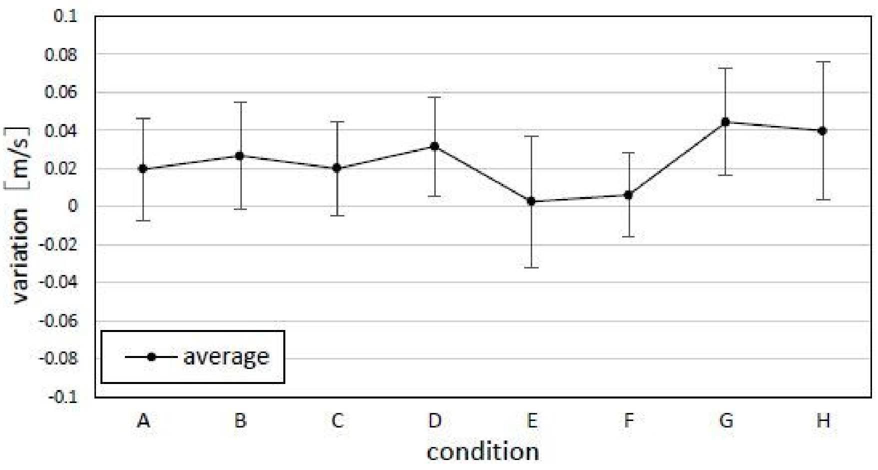

Figure 4: Variation of all condition.

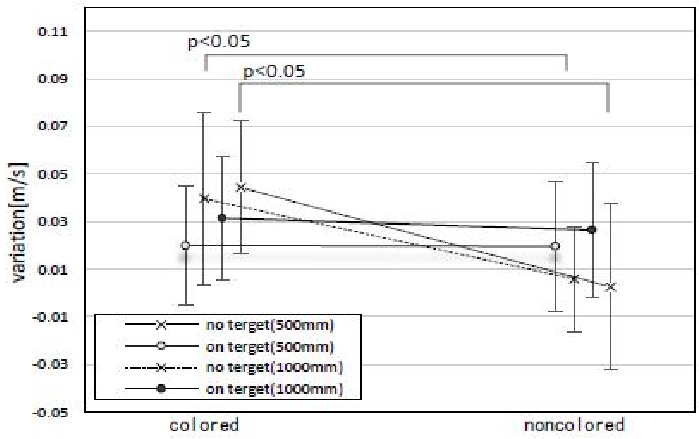

Figure 5: Variation of change in saturation.

showed no significant difference between the means of conditions G and C. However, in Figure 6 and Table 1, a multiple comparison test of standard deviations with the target as a factor (level 1%) detected a significant difference. In the presence of a target, subjects' gaze was mostly directed toward the target, while in the absence of a target, subjects were found to be looking around. In the former case, the wall surface was perceived mainly in the peripheral vision, while in the latter case, the wall surface was perceived more

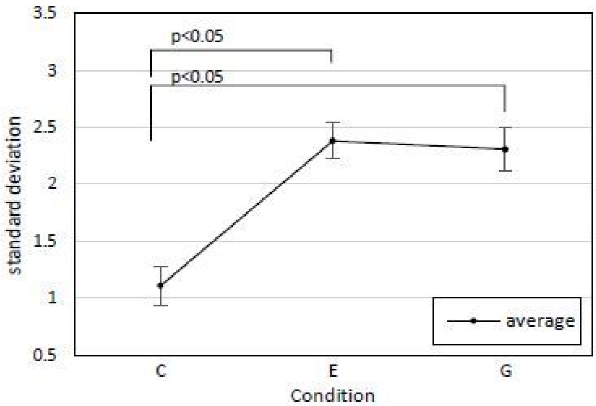

Figure 6: SD of condition C, E and G.

Table 1. Average and SD of X coordinate.

X coordinate of gaze point		
condition	average	SD
C	0.314	1.107
E	−0.245	2.379
G	0.381	2.304

often in the central vision. In other words, when the wall surface pattern was perceived in the peripheral vision, it was difficult to distinguish the different colors of the wall surface, suggesting that there was no effect on walking speed.

In conditions E and G, differences in walking speed were observed due to differences in color. Comparing these two conditions, we will analyze the influence of the presence or absence of a target on eye movement. In these cases, no difference was found in the analysis of X-coordinates. Therefore, an analysis of the Y-axis coordinates of the vertical vibration was conducted. For comparison, a 6m high wall was divided into lower (0 m ~ 1.5 m) and upper (1.5 m ~ 6 m) sections based on the subject's eye level. The gazing rate during walking for each area was calculated. Table 2 Y coordinate shows that the subjects gazed at the lower part 27.40% and 75.90% for condition E and 24.10% and 75.90% for condition G, indicating that the subjects gazed at the upper part more frequently in both conditions. The mean values were 1.87 for condition E and 2.07 for condition G. This suggests that a high percentage of subjects looked up at the walls of the experimental space, especially around 2 m from the wall, which may have some effect on walking speed.

Table 2. Y coordinate analysis.

Y coordinate of gaze point				
condition	**average**	**SD**	**ratio of gaze**	
E	1.867	1.306	0m ~ 1.5m	27.40
			1.5m ~ 6.0m	72.60
G	2.067	1.131	0m ~ 1.5m	24.10
			1.5m ~ 1.5m	75.90

CONCLUSION

The analysis showed that the average walking speed was significantly higher in the coloring condition than in the noncoloring condition, especially when the gazing point was not fixed in the direction of travel. When the participant's gaze position was fixed, this significant difference in "colorfulness" could not be confirmed. This may be due to the ability of the peripheral visual field. The peripheral visual field has a lower color discrimination ability than the central visual field. While the gaze position was fixed in the direction of travel, side walls were perceived primarily in this peripheral vision. Therefore, it is thought that the effect of color was less apparent. Analysis of gazing point coordinates revealed that the effect on walking speed may be related to the texture and color of the lower part of the wall surface.

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