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Effects of Design Around a Window on the Mental Strain of a Person Working at a Desk

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ABSTRACT

When working in a room, people may choose to work around a window for a sense of openness and recovery of fatigue. However, design around a window (for example, the size of a window and the distance from the sidewalk) may have a negative effect on mental strain, such as decreased concentration on work. In this study, we examined the effects of design around a window on the mental strain of persons working at a desk through a subjective experiment using both virtual environment technology and an electrodermal activity measurement method. This study is a part of ongoing research aimed at obtaining knowledge about design around a window that does not cause mental strain. A total of eleven students participated in the experiment. We arranged floor-to-ceiling height windows and a moving virtual human avatar in the virtual environment. The subjects experienced these conditions while performing a task in the virtual environment. The results showed that the narrower the window width, the higher the mental strain on the person working at a desk. Moreover, the mental strain varies depending on the existence of a task or not.

Keywords: Window, Mental strain, Immersive virtual environment

INTRODUCTION

One may sometimes chose a window seat in a space as a place to work or study. There are many previous studies on the positive psychological effects of windows. For example, through analysis of living environment evaluations, Muto et al. clarified that the window's psychological effects can be categorized into comfort and introduction of a sense of continuity with the outside world. Also, Won et al. clarified positive emotions increased while negative emotions decreased with windows. However, such studies have generally verified assuming situations in which the scenery outside the window does not change so rapidly. In many cases, various changes occur from time to time outside a window, and the visual stimulation caused by human movement is considered to cause mental strain to the person [seated] in the room.

In a previous report, we constructed multiple window widths and moving human avatars in a virtual environment, and verified the effects of each variable combination on the mental strain of a person staying in the room. It was found that changes in window width and the distance between the person staying in the room and the person passing outside the window affect the mental strain of the former.

In the present study, using virtual environment technology and skin potential measurements, we examined the effects of design around a window, such as changes in window width and the distance between the person passing outside the window and the person in the room, on the mental strain of the person working in the room. The purpose of this study is to obtain data on architectural planning that will lead to a reduced mental strain in the people working, thereby increasing their concentration on their work.

EXPERIMENT

Summary

Subjects performed a task in a virtual space. We measured the subjects' skin potential responses and task performance during this process to verify the relationship between the design around a window and the subjects' mental strain.

Subjects experienced a virtual environment through a head-mounted display (HMD). A rectangular space with a window created with virtual environment software (vizard6.0/WorldViz) was presented to the HMD (VIVE PRO EYE/HTC Corporation) via transfer software (Virtual Desktop/Virtual Desktop).

Eleven students participated in the experiment. The experimental site was a virtual environment laboratory at Chiba University, Japan.

Conditions

The size of the rectangular space constructed in the virtual space was 3000 mm wide x 2500 mm deep x 3000 mm high. On the wall of one long side of the space, an opening of 3000 mm in height from the ceiling to the floor was created and designated as a "window". The subject sat facing the window at a distance of 800 mm from it. A 300 mm x 200 mm screen linked to a laptop computer was also displayed in front of the subject to perform the task.

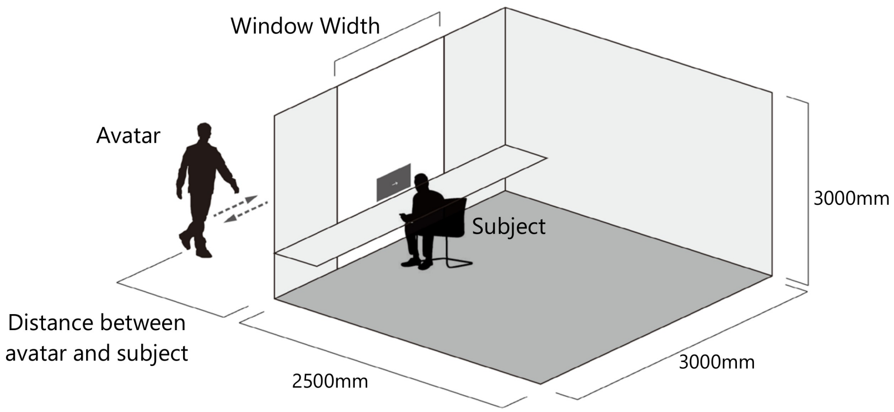


Figure 1: Experimental environment.

Table 1. Image in each condition.

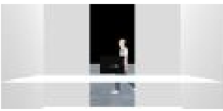
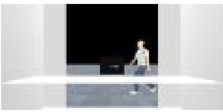
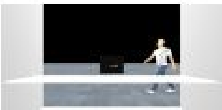
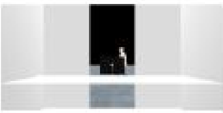
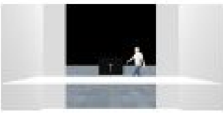
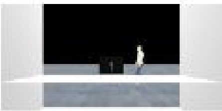
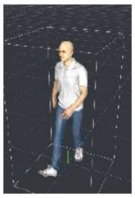
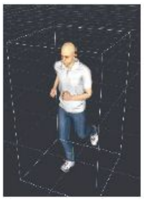
		Window Width [mm]		
		1000	2000	3000
Distance between avatar and subject [mm]	1000			
	2000			

Table 2. Images of avatar.

Name	1. walking	2. jogging	3. striding
VR Image			
Speed	4 km/h	6 km/h	4 km/h

We set three factors: three levels of window width (1000, 2000, and 3000 mm), three types of avatar (1. walking, 2. jogging, and 3. striding), and two levels of distance between avatar and subject (1000 mm and 2000 mm).

Method

After explaining the outline of the experiment, each subject was fitted with a HMD and a skin potential meter TS02 SPL/R-AD (Technonext, Inc.). The skin potential meter was attached to the subject's left hand at three locations: the base of the thumb, wrist, and back of the hand. The subject was instructed not to move the left hand with the skin potentiometer attached. During the trial, subjects also performed the task with their right hand. The task was in the form of typing arrow keys corresponding to the arrows displayed on the screen.

In one trial, three different avatars (1: after 15 seconds, 2: after 50 seconds, and 3: after 80 seconds) appeared within 90 seconds under certain conditions. Six conditions were presented in random order, including three levels of window width and two levels of avatar-subject distance. There was a 10-second break between each trial, and subjects were asked to close their eyes before restarting.

ECTRODERMAL ACTIVITY

Miyata et al. states that "skin potential response (SPR) is the AC component of skin potential activity (SPA), which occurs in response to stimuli such as visual and tactile stimuli caused by external environmental changes."

The following method by Kobayashi et al. was employed in the present study to analyze the skin potential response. First, the amount of response of the yin-yang biphasic wave that appeared within 3 seconds of the appearance of the avatar was calculated and named as RX. Then, 15–20 seconds after the appearance of the avatar was set as the measurement time of the reference value. The absolute value of the maximum and minimum values within this reference measurement time was used as the reference value, and named as R0. RX/R0 was calculated for each skin potential response, and this value was defined as the skin potential response ratio. The higher this value is, the more mental strain is imparted on the subject.

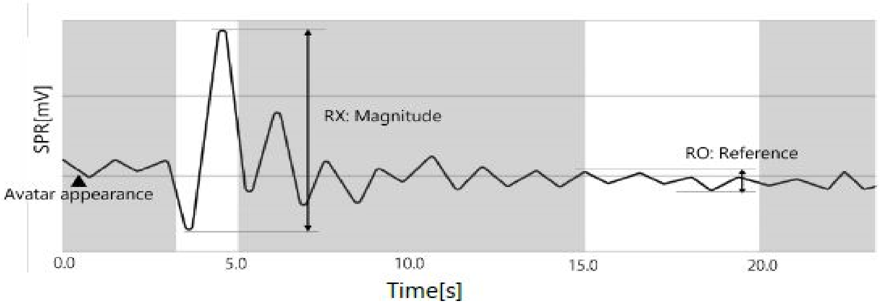


Figure 2: Schematic graph of skin potential response.

RESULTS AND DISCUSSION

Skin Potential Responses

Bonferroni's multiple comparison tests (t-test, 5% level) were conducted on three factors: window width level, avatar types, and distance level between the avatar's passing motion line and the subject. First, for each avatar, a significant difference was found between the window width of 1000 mm and 3000 mm only for avatar 1.walking (Figure 3).

In addition, regarding the avatar level and SPR at each distance, only at 2000 mm distance between subject and passing avatar, significant difference between 1.walking and 3. striding and significant difference trend 2.jogging and 3.striding were found (Figure 4). This indicates that the faster the avatar moved, the greater the skin potential response. For avatars with the same movement speed, the more prominent the movement, the greater the skin potential response. Although both 1000 and 2000 mm distances show similar trends, the difference in values is smaller at 1000 mm distance (Figure 4). This is may be due to the difference in whether the avatar's entire body is visible or not. The difference in values could be due to the fact that the avatar's whole body is visible, which makes it easier to see differences in the avatar's movement and speed.

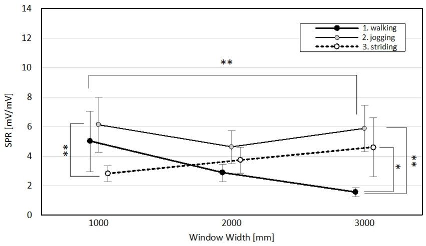


Figure 3: Relationship between window width and SPR in each avatar.

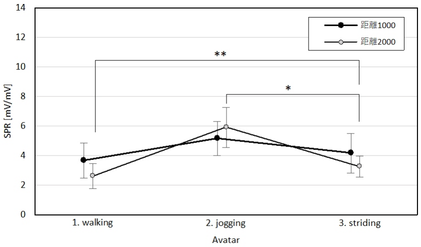


Figure 4: Relationship between avatar and SPR in each distance.

Task Performance

In this experiment, reaction speed to the task was evaluated as the work performance. Reaction speed refers to the time from when the arrow appears on the monitor until the time that the subject types the arrow key. Figure 5 shows a comparison of reaction speed with the distance between the avatar passing motion line and the subject at each window width level. Bonferroni's multiple comparison tests (t-test, 5% level) were conducted on the two factors of window width level and the distance between the avatar passing motion line and the subject, but no significant differences were found. However, reaction speeds were slower from 1000 mm to 2000 mm distance for all window width levels.

Comparison With Previous Experiments

We compared the data of this experiment with those of a previous experiment in which the same procedure was performed but without the task. Bonferroni's multiple comparison tests (t-test, 5% level) were conducted using the window width level, the distance level between the avatar and the subject, and the presence of a task as factors.

Figure 6 shows the relationship between window width level and skin potential response ratio with and without task. As a general trend, the skin potential response ratios in the tasked condition were lower than those in the non-tasked condition. In addition, the wider the window width, the smaller the mean skin potential response ratio. The test results showed a significant trend between the window widths of 1000 mm and 3000 mm for both the

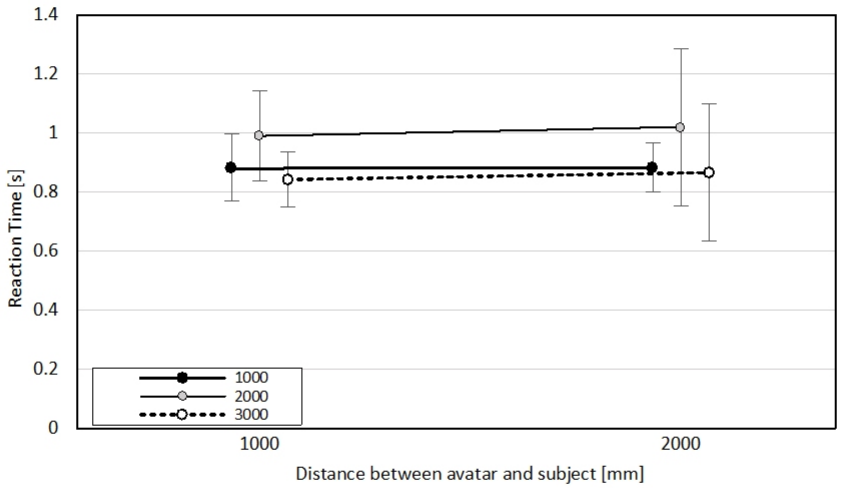


Figure 5: Relationship between distance and reaction time in each window width.

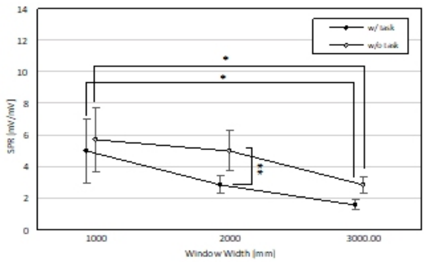


Figure 6: Relationship between window width and SPR in each task condition.

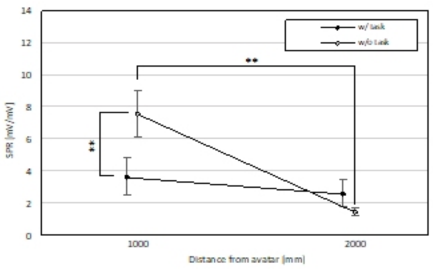


Figure 7: Relationship between distance and SPR in each task condition.

tasked and untasked conditions. This indicates that regardless of the presence or absence of a task, maximally widening the window width reduces the mental strain of the occupants.

Figure 7 also shows the relationship between the distance level between the avatar passing through and the subject and the skin potential response in the presence and absence of the task. The overall trend is that the shorter the distance between the avatar and the subject, the smaller the average skin potential response ratio, regardless of the presence or absence of a task.

However, the values changed more significantly in the no-task condition, confirming a significant difference. In the no-task condition, subjects were looking out the window and centered on the avatar. On the other hand, in the tasked condition, subjects gazed at the task monitor, and thus may have had a peripheral view of the avatar. We believe that this difference caused the difference in the amount of change in the skin potential response ratio with and without the task. Significant differences were observed between the task and no-task conditions at 1000 mm distance between the avatar and the subject. No significant difference at 2000 mm distance was identified due to the difference in the area over which the avatar is perceived. Since the size of the avatar perceived at 2000 mm distance was half the size of the avatar perceived at 1000 mm distance, we consider that the amount and frequency of skin potential responses to the avatar were reduced in both conditions and that no difference in skin potential response ratios was observed.

With task is denoted as w task and without task as w/o task.

CONCLUSION

In this study, an experiment was conducted using window width and the movement of pedestrians passing outside the window as variables, to verify how the combination of various variables affects the mental burden of occupants performing work. By analyzing the results of the experiment, the following findings were obtained:

- When a task is imposed, the mental burden of the occupants varies depending on the speed of people passing outside the window.
- Widening the window width, regardless of whether or not a task is imposed, leads to a reduction in mental strain.

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