Impact of Viewing Distance to Virtual Screen upon Kraepelin-Task Performance and Its Psychological Fatigue

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Abstract. This manuscript discusses an impact of viewing distances to a virtual screen in an immersive environment upon psychological fatigue by assessing calculation performance of Kraepelin test. The viewing distance can be adjusted from 0.5 m to 128 m. The result shows that there is a certain tendency to alleviate psychological fatigue at the furthest viewing distance.

Keywords: Task performance · Kraepelin-task · Viewing distance · Virtual display

1 Introduction

The VDT syndrome is a symptom that is caused by extensive use of eyes for long hours and pains in the neck or shoulders due to sitting at desks for long periods of time, and physiological stress that stems from monotonous and continuous work requiring no errors etc.

To deal with the VDT syndrome, A. Uetake et al. [4] discussed an evaluation method of eye fatigue during VDT tasks. They found that eye fatigue is expressed as a function of pupil diameter and focusing strength. T. Katayama et al. [2] investigated the impact of color patterns displayed on a screen on work performance and fatigue. They found that an appropriate contrast between characters and background tends to alleviate much more fatigue. Y. Kato et al. [3] built a posture feedback neck band to alleviate pain in the neck and shoulders. The users wear the band on their neck and the band rings an alarm when their posture becomes misaligned during VDT tasks.

In regard to human ergonomics, international standards of ISO9241-303 specify requirements for output devices, especially for electronic visual displays. It says for example that the viewing distance, which refers to the physical distance between the surface of the computer screen and the user's eyes, should be 30 to 40 cm for children and young people, and more than 40 cm for adults and older

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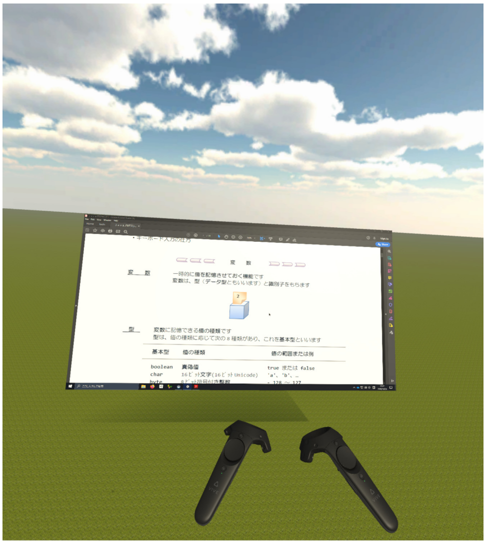

Fig. 1. Screenshot of the HMD view.

people. Though a lot of approaches and efforts from various points of view have been made to address VDT syndrome over the years, it still remains a problem for many office workers.

As mentioned, optimal viewing distances have been discussed often from the side of human ergonomics but not task performance. Previously, the authors [1] showed that long viewing distances to a computer screen could improve performance of mouse manipulation in terms of speed and accuracy. In their study, two experiments of tapping and tracing tasks (ISO9241) were conducted for three viewing distances of 0.5 m, 32 m and 128 m from a virtual computer screen in an immersive virtual space provided by an HMD. This study aims to cover discussion about the impact of those viewing distances on psychological fatigue by including a calculation task of Kraepelin test.

2 A HMD-Based Virtual Display Environment

The system consists of a HMD device of HTC Vive Pro and a high-end host computer of Dell Alienware. The HMD is connected to the host computer and the host computer runs Unity (2019.1.14f1) to compose a virtual space where a virtual computer screen is placed. Figure 1 shows a screenshot of the HMD view which the user sees in. There is a virtual computer screen in that view and the user manipulates the contents on it. The contents on the virtual computer screen come from the host computer and all the input made on the virtual computer screen like mouse clicks and drags, goes back to the host computer to update the contents. The user can adjust its viewing distance in real time with a Vive trackpad. The viewing distance can be adjusted between 0.5 m and 128 m.

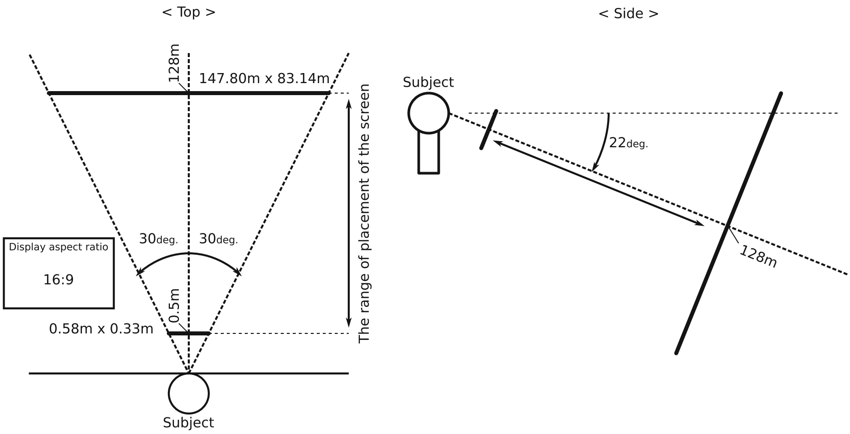

Fig. 2. Experiment design.

3 Experiment on Calculation Performance

The aim of this experiment is to evaluate an impact of viewing distances on calculation performance. Figure 2 shows the design of the experiment. The left diagram shows the top view and the user sees a virtual computer screen just in front of him/her. The virtual computer screen is enlarged with a constant horizontal FOV of 60 degrees as the viewing distance becomes long. The user perceives a small screen at the short viewing distance and does a large screen at the long distance. The right diagram shows the side view and the virtual computer screen is placed along a line at the angular position of 22° below the eye level according to ergonomics of human system interaction in ISO9241. Three constant viewing distances of 0.5 m, 32.0 m and 128.0 m are given for each subject to perform the given task. The three constant viewing distances are referred to as Near, Middle and Far, respectively.

3.1 Tasks and Subjects

Each subject is asked to perform Kraepelin test at each condition:Near, Middle and Far. Kraepelin test measures accuracy and speed of addition of a 1-digit number to a 1-digit number. Figure 3 shows a look of Kraepelin test and the subjects are asked to add a number to the adjacent number from left to right and answer the first digit of the obtained value as many and correctly as possible in 15 min. During the test, the elapsed time, the count of total answers and correct ones for measuring calculation performance, and a sequence of heart beats for measuring psychological fatigue are measured. Before and after the test, a flicker perception threshold or FPT is obtained for measuring psychological fatigue as well. For measuring physical fatigue, they are asked to fill out a questionnaire defined in ISO9241 after the test.

9		4		6		6		7		6		4
	3		0		2		3		3		0	
2		5		0		7		8		9		1
	7		5		7		5		7		0	
6		2		6		4		9		6		9
	8		8									
5		1		7		8		9		7		4
5		6		8		7		8		1		0
2		2		0		9		6		3		3

Fig. 3. Calculation sheet of Kraepelin test.

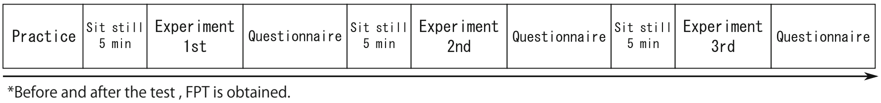

Fig. 4. Procedure of the experiment.

There are 14 subjects aged from 21 to 24. They are students from a course of computer science and engineer in our university and all are right-handed and have experience with manipulating a computer mouse. They also have good eyesight.

3.2 Experiment Procedure

Figure 4 shows a procedure of the experiment. The subject has a practice time to become familiar with the test before it begins. After that, he/she sits still for 5 min then starts the test at one of the conditions of Near, Middle and Far, and fills out a questionnaire about his/her physical fatigue. He/she sits still for another 5 min then starts the task again at the other condition and fills out the questionnaire. The order of conditions between Near, Middle and Far is balanced among subjects to remove order effects. Each subject performs one trial at each condition, resulting in

$$14 \text{ subjects} \times 3 \text{ conditions} \times 1 \text{ trial} = 42 \text{ trials in total.} \quad (1)$$

3.3 Results

Figure 5 shows the speed of calculation. The horizontal axis shows the three conditions of Near, Middle and Far, and the vertical one does the total number of answers among subjects on average at each condition and the corresponding standard deviation. From the figure, there seems not to be a relation between those conditions and the speed of calculation. Figure 6 shows the performance of calculation. The horizontal axis is the same with Fig. 5 and the vertical one shows

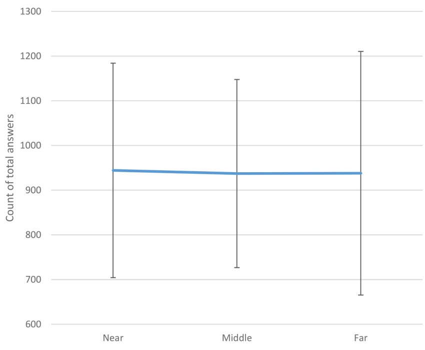

Fig. 5. Speed of calculation defined as the total number of answers among subjects on average at each condition and the corresponding standard deviation.

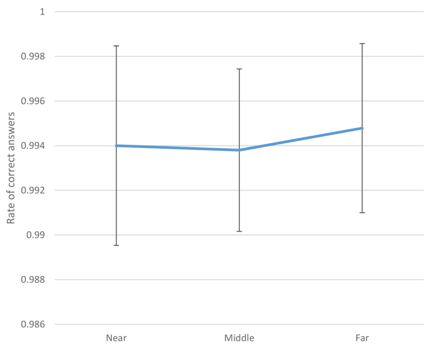

Fig. 6. Performance of calculation defined as the percentage of the number of correct answers for the total one among subjects on average at each condition.

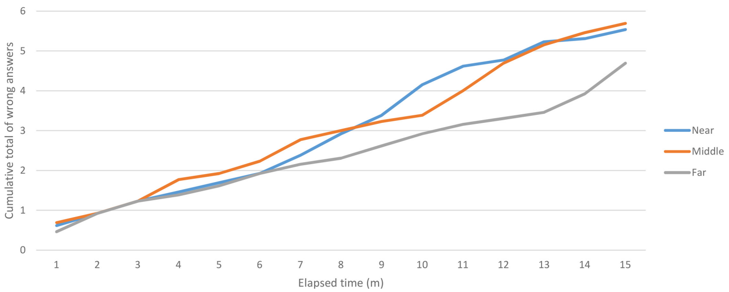

Fig. 7. Cumulative total of wrong answers per minute.

the percentage of the number of correct answers for the total one among subjects on average at each condition. From the figure, there is a certain increase in the percentage at the Far condition. Figure 7 shows the temporal performance of calculation. The horizontal axis shows the elapsed time in minute and the vertical one does the cumulative total number of wrong answers. From the figure, there seems a tendency to hold calculation performance at the latter half of the test.

Figure 8 shows physical fatigue. The horizontal axis shows the conditions and the vertical one does the questionnaire score among subjects on average at each condition. From the figure, physical fatigue tends to be alleviated at the farthest viewing distance except for the eyes.

Figure 9 and Fig. 10 show psychological fatigue, and they are obtained from Flicker test. The Flicker test provides a subjective indicator of the psychological fatigue by asking the subject to see a light switching between on and off fast, and judge the timing of transition between continuous perception of the light and intermittent one. The timing is measured as the number of counts of flickering light per section and it is called Flicker Perception Threshold or FPT. FPT holds

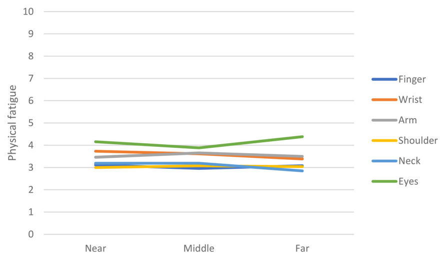

Fig. 8. Physical fatigue.

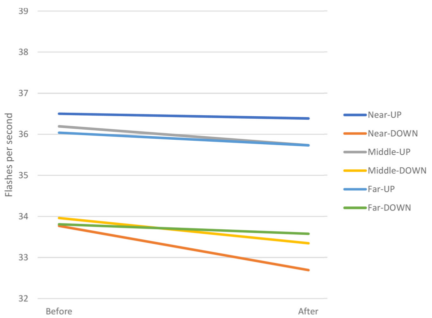

Fig. 9. Obtained FPTs from an increasing order of frequency (UP) of flickering light or a decreasing one (DOWN).

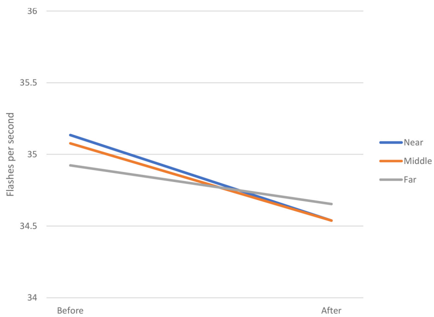

Fig. 10. Obtained FPTs among UP and DOWN on average.

comparatively high when the psychological fatigue is low or vice versa. Generally, FPT differs when it is measured from an increasing order of frequency (UP) of flickering light or a decreasing one (DOWN), and the FPT obtained from UP is often larger than the one from DOWN. Figure 9 is a pair of FPTs obtained from UP and DOWM among subjects on average before and after the test for each condition. From the figure, validity of the test is confirmed. Figure 10 shows FPTs among subjects over UP and DOWN on average before and after the test for each condition. From the figure, psychological fatigue becomes large after the test in comparison with the one before it for all the conditions. The amount of increase of psychological fatigue holds the smallest for the farthest condition.

Figure 11 and Fig. 12 show psychological fatigue as well, and they are obtained from the subject's heart rate (RRI). By carrying out a spectral analysis of the given RRI sequence, the ratio of LF (the spectral integration at 0.05 to 0.15 Hz) to HF (the spectral integration at 0.15 to 0.40 Hz) is used to express an index of psychological fatigue: relax (0.0∼0.8) and high psychological fatigue (2.0∼5.0) according to Fatigue Science Laboratory Inc. A moving window of 5 min is employed to carry out the analysis and observe changes of the index of LF/HF per second through the test. Figure 11 is a list of graphs showing the change of the index over the test for each of 6 subjects. The data of RRIs from

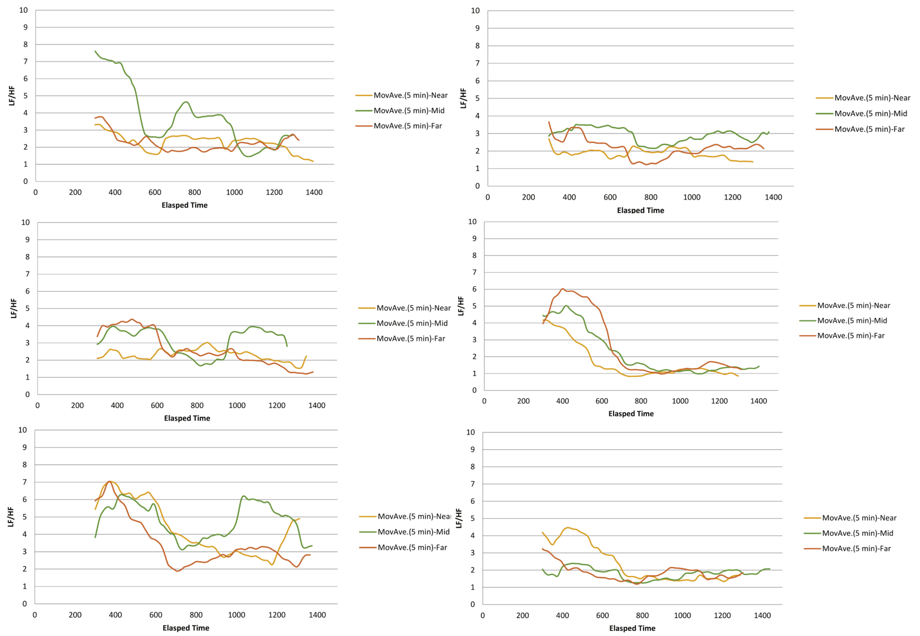

Fig. 11. Temporal change in LF/HF obtained from 6 subjects. The data from the left 8 subjects was corrupted due to the device failure.

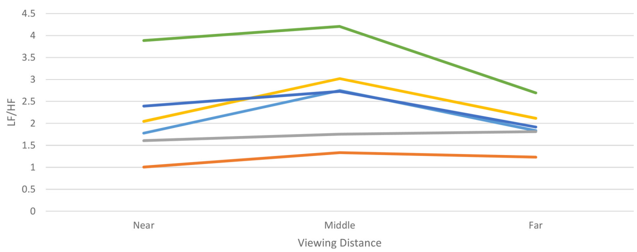

Fig. 12. Average of LF/HF at each condition.

the left 8 subjects was corrupted due to the device failure. The horizontal axis is the elapsed time in second and the vertical one the index of LF/HF for each condition of Near, Middle and Far. From those graphs, psychological fatigue tends to be alleviated at the farthest viewing distance.

Figure 12 is a graph showing the index of LF/HF over the test on average at each condition for each subject. The horizontal axis shows the conditions and the vertical one does the index of LF/HF. From the graph, the amount of alleviation of psychological fatigue tends to vary depending on subjects.

3.4 Conclusions

This manuscript discussed an impact of viewing distances to a virtual screen in an immersive environment upon psychological fatigue by assessing calculation performance of Kraepelin test. The result showed that there is a certain tendency to alleviate psychological fatigue at the furthest viewing distance. In future work, the authors are going to conduct a further experiment with more subjects and another calculation task.

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