CHANGES IN WORKLOADS DURING 120 MINUTES OF WORK WITH MONOCULAR HMD: COMPARISON WITH MOBILE VIEWER VIEWING VIDEO

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Abstract: A portable monocular head mounted display (HMD), which has one viewer with a display, which captures images, and the other viewer with no display, may impose a different workload from that imposed by a mobile binocular viewer, which presents one image to both eyes. The subjects watched cartoon videos for 120 minutes in total, and a comparison of workloads and physiological indexes between both devices was made. No significant difference was recognized between the two devices, however, significant increase in workloads was shown around 80 minutes compared to before task with the monocular HMD. Moreover, it is indicated that there is a boundary zone around 90 minutes during continuous viewing with the monocular HMD according to the fact that an inflection point appeared around 90 minutes in the reaction time on the Stroop color-word conflict test and blink frequency.

1. INTRODUCTION

The mobile monocular head mounted display (HMD) mainly consists of a viewer wearing a display, which provides images to one eye, and a viewer wearing no display, which captures images around the user. Though both eyes see the front, as the way of viewing is different from usual, it is expected that the monocular HMD may impose a different workload on a user from that of a device with the same mobility, which see the same image with both eyes. The monocular HMD is considered to be useful for, for example, viewing images while moving as a small device with a big screen, making use of its mobility. However, only a few researches have been done on changes in workloads during viewing video (Peli, 1998), it will be important to study the workload change and to consider continuous viewing time or break time. And, comparison with a mobile viewer, which is already on the market, would be appropriate in a sense to survey the workloads. In this study, we compared the changes in workloads during 120-minutes of video (DVD) viewing with MBL (mobile viewer), targeting mobile usage for viewing entertainment such as news, weather forecast, and sports. The aim of the study is to reveal the changes in workloads during viewing video for a long time with the devices, and to analyze the degree of influence of the change and timing to insert interruption.

2. METHOD

2.1 Participants

Nine healthy male students (aged 22±2, 19 to 26 years old) took part in the experiment.

2.2 Experimental Conditions

With the monocular HMD, the optically specified viewing distance is 1m on a 17-inch monitor. MBL (2.5 inch) was fixed on the board keeping a proper VDT viewing distance of 40cm, with the depression angle at 15 degree from a normal viewing angle. The monocular HMD is worn over the dominant eye (right-eye 7, left-eye 2), and the subjects were seated on the chair in both cases (positive value). The background color of
the viewing environment was plain and the horizontal illuminance was set to 700 lx (screen illuminance is 420 lx), assuming a normal environment.

2.3 Experimental Task

Twelve 10-minute short stories of Doraemon, in which average preference can be expected, were edited into a total 120-minute video (actually, two kinds of 120-minute video were made so that the subjects would not see the same stories). As video viewing experience includes passive factors, a yellow mark was displayed on one of four corners of the screen and the subjects were required to respond when it appeared on the screen with a mouse to avoid no-viewing or sleeping. Conditions such as content of video and device were randomized.

2.4 Experiment Procedures and Measuring Items

The subjects took a 10-minute full rest, and after that, they started video viewing. Five questions about workloads like vision were prepared to understand the state of workloads during viewing. Stroop test; the color word conflict test was conducted on each display, which creates the condition to interrupt attention; “Psychological interference”. In this test, one Chinese character printed in a different color from its meaning, such as red, blue, green, and yellow, was displayed for 200 ms, and the subjects were asked to verbally identify the color or the word (Duncan-Johnson, 1981; Ilan, 1999). Furthermore, two circles printed in red and blue which require “selective attention” were displayed every 30 minutes during viewing (for 500 ms) and the subjects were asked to push the button when the red circle came on, aiming at brainwave measurement with 30/150 targets (displayed for 500 ms) with P300 as an index (McCarthy, 1981; Ilan, 1999). Electrodes were placed on Fz, Cz, and Pz (10/20 method). With a 20-minute full rest period, the presence of recovery processes was observed related to the workloads of 2-hour continuous viewing. A symptom questionnaire was given to the subjects before and after video viewing and after the rest period after task (issued by Research Group for Occupational Fatigue, Japan Society for Occupational Health) and eye accommodation function and visual functions were measured. As physiological data, blinking frequency using EOG and cerebral blood volume on the forehead (monitor depth is 18-21 mm) using NIRS in addition to EEG described above.

3. RESULTS AND DISCUSSION

3.1 Subjective Symptom Survey

The survey consists of 25 items in five categories. When the value before task is set to 1, the value after video viewing is likely to be significantly higher in the category of “Drowsiness” and “Blur” than the other categories with the monocular HMD (P<0.05, Wilcoxon test). The value in the category “Blur” after task is only significantly higher with the monocular HMD than that with MBL (P<0.05, Wilcoxon test), and no significant difference was found after rest.
3.2 Fatigue Portions and Visual Workloads Survey

Not many complaints accompanied by sitting posture were made in the fatigue portions survey. Earache caused by using a headphone, which continued after rest period, is one of the factors to be improved, and fatigue was occasionally reported in the shoulders, neck, low back, and so on as well as in the eyes. Figure 1 shows the results of the visual workload test with 21 items (on the 3-point scale). A three-way ANOVA (subject × time (elapsed time) × device factors) using the average value of subjects, with the value before task set to 1, revealed main effects of the time factor ($F_{2,16}=53.599$, $P<0.001$). No difference between the devices and no interaction between time and device factors were recognized. The change rate indicates a significantly higher workload after task and after rest than that before task with both devices ($P<0.05$, Wilcoxon test). After rest, there was no significant difference between before and after task, and complaints continued. With both devices, major complaints, such as increase of blinking and difficulty keeping eyes open, are included in the subjective symptom survey according to the average value of the subjects.

3.3 Device Usability

A questionnaire was used for device’s usability studies, including device’s heaviness, easiness to view, screen visibility, easiness to handle, shoulders and neck stiffness, and wearing stability. The results can be summarized that the molecular HMD shows stable fit of the display, and reduction in workloads related to prolonged viewing and posture when viewing. MBL shows the similar results, except for stable fit, and far viewing distance.

3.4 Question about Workloads like Vision during Viewing

Five questions are (1) eye fatigue (2) workload of wearing a monocular HMD (3) workload of wearing a headphone (4) drowsiness and dullness (5) desire to watch the next video (ten-point scale). Figure 2, which shows the relative changes with time on the item (1) when a resting value before task is set to 1, indicates that workloads are likely to increase with both devices. The 3-way ANOVA (subject × time × device factor) reveals main effects of time ($F_{14, 98}=29.526$, $P<0.001$) and device factors ($F_{1, 98}=92.031$, $P<0.001$), which are higher with MBL, and interaction was observed between time and device ($F_{14, 98}=1.573$, $P=0.10$). For the question (4), main effects were recognized only on time factors ($F_{14, 98}=24.381$, $P<0.001$). For the question (4), main effects were detected for time ($F_{14, 98}=24.541$, $P<0.001$) and device factors ($F_{1, 98}=24.541$, $P<0.001$)(higher with MBL), however, no interaction was found between them. For the question (5), as well as the question (1), main effects were detected for time ($F_{14, 98}=39.280$, $P<0.001$) and device factors ($F_{1, 98}=56.084$, $P<0.001$) (lower with the monocular HMD), and interaction was found between time and device ($F_{14, 98}=1.787$, $P=0.05$). For all items from (1) to (5), a difference with the first resting was recognized after 70 to 80 minutes (Tukey method). As for the monocular HMD, a difference appeared at 80 minutes (MBL: 60 min.) for (1), 100 minutes for (2), 90 minutes (MBL: 50 min.) for (3), 70 minutes (MBL: 50 min.) for (4) and 70 minutes (MBL: 80 min.) for (5), difference is likely to appear earlier with MBL.
3.5 Eye Accommodation Function

Figure 3 shows the changes in eye accommodation tension speed. Though the symptom survey revealed a significant difference in “Blur” between two devices, the changes in the accommodation tension speed, with the value before task set to 1, indicated a significant reduction after task with both the monocular HMD and MBL (Monocular HMD: P<0.10, MBL: P<0.05, t-test). With the monocular HMD, the significant tendency was observed even after rest (P<0.10, t-test). No significant difference as a relative change value of accommodation relaxation speed after task was detected in both devices.

3.6 Visual Acuity

On the dominant eye with the monocular HMD, a significant difference in reduction of near and far visual acuity was revealed only between before and after task (P<0.10, t-test), however, it was recovered after the rest. A significant difference (P<0.05, t-test) in reduction of near vision of the non-dominant eye was only recognized between before and after task, and it was recovered after rest, same as the dominant eye. This tendency was not observed for the far visual acuity. The display of the monocular HMD was put on the dominant eye. The display target is 1m away, and as the non-dominant eye does not wear a display, it has no target to focus on. As for the monocular HMD, it was indicated that reduction of accommodation speed occurred in the near and far visual acuity for the dominant eye (wearing a display), and in the near visual acuity for the non-dominant eye (wearing no display), and it was recovered after rest in both cases.

3.7 Stroop Test

The subjects read the Chinese character or identify the color; red, blue, green and yellow. The psychological interference increases when attention is interrupted, which is considered to affect the reaction time. The experiment of video viewing was not an active test, in which the subjects only received content, and there were no elements requiring them to act on. However, it was assumed that time-course changes would occur if workloads of 120-minutes of video viewing lead the reduction of attention, and ability to think and judge. Figure 4 shows the changes with time in the reaction time of both devices. Significant shortening was recognized at 50 minutes (P<0.10, t-test) and 90 minutes (P<0.05, t-test) compared to before task with the monocular HMD. The monocular HMD shows the tendency to delay at 100, 110 and 120 minutes (P<0.10 or less) from 90 minutes. That indicates 90 minutes is the boundary zone. With MBL, a significant difference was recognized at every point after 30 minutes (P<0.05, t-test) compared to before task. With MBL, the reaction time tends to be shortened with time. With the monocular HMD, 90 minutes is generally the point where the response time begins to slow down.

3.8 Blink Frequency

Figure 5 shows the changes in the number of blinks. A two-way ANOVA(subject × time) revealed main effects of time with the monocular HMD (Monocular HMD: F[14, 112]=1.687, P<0.10). With the monocular
HMD, significant reduction in blink frequency was recognized at 70 and 110 minutes (P<0.10 t-test) compared to before task rest. The reduction of blink frequency, though not significant, was recognized at every point after 90 minutes with the monocular HMD, which indicates the subjects were forced to keep gazing the screen. After the rest period after task, both devices show a recovery tendency as the condition returns to the same level at the first rest. No significant difference was recognized between the devices; however, the tendency of the molecular HMD begins to separate from that of MBL after around 80 minutes on the graph. The difference in tendency after 80 minutes is significant, which can be the boundary value for continuous use of the molecular HMD. Considering that significance was also recognized in the symptom of blur with the molecular HMD at the subjective symptom survey, the value will be useful as a physiological index of subjective symptoms.

3.9 P300

3.9.1 Latency

Based on the delay and shortening of P300 latency in selective attention when a target is captured, P300 latency delay was assumed on the assumption that attention would be reduced after 120-minute continuous
video viewing (Trimmel, 1998). Both devices showed no main effects of time in 2-way ANOVA (subject × time). A significant difference was recognized at after rest in MBL (P<0.10, t-test). At the point of 90 minutes, a more significant delay was observed in the monocular HMD than MBL (P<0.10, t-test). This indicates that the monocular HMD would impose a larger workload than MBL at the point of 90 minutes. Though it is a matter of comparison between devices, based on the level of MBL, the boundary zone for using the monocular HMD seems to be within 90 minutes (the delay starts at 90 minutes).

3.9.2 Amplitude

It is considered that, as well as the latency, the increase/decrease of P300 amplitude for attention increases in proportion with workload accompanied by attention (Ullsperger, 1988). When P300 amplitude was observed over time, no main effects of time was recognized in 2-way ANOVA (subject × time) in both devices. There were no significant differences with before task at any points in both devices. A significant difference between the monocular HMD and MBL was recognized at 30 minutes (P<0.10, t-test). An increase in attention was recognized in the monocular HMD after 30 minutes of viewing, however, it significantly reduced for the rest 60 minutes (P<0.05, t-test). It might be the state of initial efforts of the monocular HMD.

3.10 Cerebral Blood Volume

HbI shows the change rate of hemoglobin and volume of blood supply in capillary blood directly under the sensor. Increase in HbI indicates the increase of blood volume under the sensor compared with the values at the beginning of the monitoring. Unless lung disorder decreases the gas exchange ratio, the increase and decrease of HbI can be regarded as that of oxygen supply volume. Figure 6 shows the change of HbI-R with time. HbI-R (the right side of the brain) showed no significant reduction during viewing compared to the value at rest period with both devices (Tukey test); the state after rest period is similar to that before task.

4. SUMMARY AND CONCLUSIONS

Changes in workloads of the mobile monocular HMD and MBL were studied using the subjective index, physiological index, and response time. Subjective evaluation reveals increase of workloads related to visual symptoms in both devices. With the monocular HMD, it seems to be necessary to approximate the visual balance between the eye wearing a display and the eye wearing no display. Feeling of workload during viewing was seen a little earlier in MBL; however, it is actually a hand-held device. The symptom of stiffness in shoulders and neck is common to both devices. Regardless of device, workloads were not relieved after rest, so sufficient rest time should be taken if appropriate recovery of subjective symptoms is expected. Subjectively, users can enjoy a normal size display on a commuter train or bus in a casual way as far as for 70 to 80 minutes. According to the recovery of accommodation tension, attention subjects and tendency of blinking frequency, up to 120 minutes or 90 minutes are indicated, so a drastic idea of
60-minute-rest is suggested. However, considering its entertainment value, flexible use is recommended with the boundary value set to before 90 minutes, as recovery effects are recognized during rest period.

5. REFERENCES