

# Influence of Display Resolution on Brain Activity and Task Workload

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**Abstract.** We experimentally investigated the influence of the use of a high-resolution 4K tablet on participants' physiological and psychological state while engaged in searching tasks, to evaluate their associated mental and physical workloads. The results showed NIRS, an index of nervous system activity, to be significantly higher during searching tasks with 4K content than with 2K content, whereas LF/HF (level of sympathetic nerve activity) during searching tasks was significantly lower for 4K content than for 2K content, although no significant differences were observed in subjective assessments between 4K and 2K displays.

**Keywords:** Physiological and psychological measurements · High-resolution 4K tablet · NIRS · LF/HF

## 1 Introduction

Developments continue in high-definition displays, with 4K products already in production and 8K displays in prospect; and various types of viewing styles, using TVs, PCs and Smartphones, make it increasingly important to consider the effects of these changes on human physical and mental health. Our view that improvements in picture quality and presence should be accompanied by reduced viewer stress and visual fatigue prompted us to investigate the influence of the use of high-resolution 4K display devices on participants' physiological and psychological state while engaged in various types of tasks, to evaluate their associated mental and physical workloads. In a prior study [1], we conducted an investigation into the effects on the physiological and psychological states of eight participants in their 20s of using a high-resolution 4K tablet while viewing various types of video content that included scenic content and video material with movement and action. The results showed the scores along the scales of "precise-coarse," "feeling of invigoration-no feeling of invigoration" and "enjoyable-boring" when viewing 4K scenic content to be significantly higher than those for 2K scenic content. Moreover, their NIRS (near infrared spectroscopic topography) values, an index of nervous system activity, during viewing tests of 4K

scenic content, were significantly higher for 4K content than for 2K content. However, further studies using various types of task will be needed to confirm whether, physiologically and psychologically, 4K viewing is superior to 2K for doing such tasks. We therefore explored and evaluated the influence of a high-resolution 4K tablet on participants' physiological and psychological state while engaged in searching tasks, which are likely to be very typical activities when using a tablet as a PC. As interim results, we reported the NIRS figures from a previous study [2]. The authors report here the results for heart rate variability (LF/HF) in addition to the results for NIRS during searching tasks, and discuss the general pattern of the results.

## 2 Methods

**Participants:** Eight adults aged in their 20s participated in this experiment. Visual acuity under 0.8 in any participant was corrected using contact lenses or glasses. Each participant gave his or her written informed consent to take part in this experiment according to the protocol approved by the Osaka City University Research Ethics Committee at the Graduate School of Human Life Sciences.

**Measurements:** The following items were investigated.

1. Subjective assessment: The participants gave a subjective assessment of their psychological state using a "subjective symptoms report" [3] before and after each task and by filling in questionnaires after each task that included inquiries as to their state on the scales of "stressed-relaxed," "comfortable-uncomfortable," "no visual fatigue-visual fatigue," etc., giving each a score of 3 to -3 (Table 1).
2. Task performance (rate of correct answers) for text-searching tasks was also calculated.
3. NIRS: Brain activity, based on total hemoglobin or oxyhemoglobin, was obtained using NIRS detectors placed on the left and right side of the participant's forehead.
4. Heart rate (HR) and heart rate variability (LF/HF; level of sympathetic nerve activity): LF/HF is defined as the ratio of the low-frequency band (LF: 0.04–0.15 Hz) to the high-frequency band (HF: 0.15–0.5 Hz) [4, 5], calculated by FFT analysis using the R-R interval based on heart rate variability obtained by electrocardiogram.
5. Blinking rate, obtained using an electrooculogram (EOG).

**Apparatus:** The display device was an A3-size 4K tablet (Panasonic UT-MB-5015SEZ).

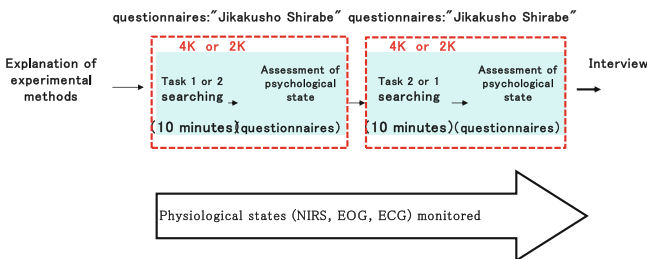
The viewing distance was set at 1.5H (45 cm). Screen-to-eye distance was defined in relation to screen height (H). The recommended viewing distance for a 4K TV, defined as 1.5 times the display's height, was 45 cm for the A3 tablet.

Test room illumination was set at 200 lx to simulate the light level of an average Japanese living room, based on JIS standardization.

**Table 1.** Subjective assessment items

| Subjective assessment items (including 15 items)        |
|---|
| The appearance of the characters                        |
| “easy to read–difficult to read,”                       |
| “precision–lack of precision,”                          |
| “precise–coarse,”                                       |
| “natural–artificial,”                                   |
| “feeling of congruity–feeling of incongruity,”          |
| “clear–not clear,”                                      |
| “slight blurring–significant blurring,”                 |
| “feeling of worry–no feeling of worry,”                 |
| “kind to the eyes–not kind to the eyes,”                |
| “no visual fatigue–visual fatigue”                      |
| The impression of the whole display and emotional state |
| “bright–dark,”  |
| “not dazzling–dazzling,”                                |
| “comfortable–uncomfortable,”                            |
| “relaxed–stressed,”                                     |
| “aroused–sleepy”  |

**Procedure:** Figure 1 shows the process of the searching task, which was to count the number of target *kanji* characters in a scrolling line of *kanji* or a stationary *kanji* layout image. Each scrolling *kanji* line included 26 Japanese *kanji* characters, taking 35 s for the whole set to scroll continuously from right to left of the screen (Fig. 2 left). Each *kanji* layout image included 25 Japanese *kanji* characters, displayed for 10 s (Fig. 2 right). One task comprised 12 scrolling lines and 12 layout images, displayed alternately. Each task comprised 10 min each of 4K or 2K content. Before and after each searching task, the participants gave a subjective assessment of their psychological state. One minute of rest time was given before each searching task, and two minutes of rest time was given afterwards. A 10-min rest was given between the 4K and 2K tasks. Physiological indices were monitored while the participants underwent the searching tests. To eliminate the order effect, the order of resolutions was made unique to each participant. Moreover, the resolution or current content was not informed to the participant, since it might have influenced their evaluation score.



**Fig. 1.** Content of searching task



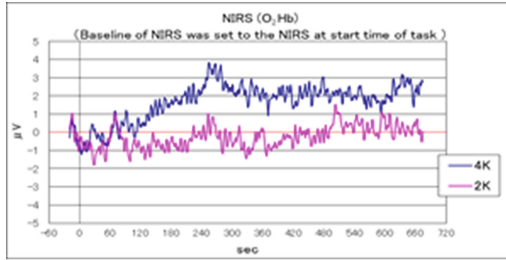
**Fig. 2.** The task was to count the number of target *kanji* characters in a scrolling line of *kanji* (left-hand figure) and in a *kanji* layout image (right-hand figure).

**Statistical analysis:** A paired t-test was performed to analyze the influence of the display resolution. The level of significance was set at  $p = 0.05$ .

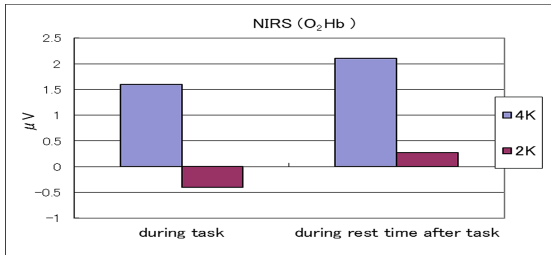
### 3 Results and Discussion

The results showed that during searching tasks, NIRS, an index of nervous system activity, tended to be higher for 4K content than for 2K content [2]. The graphs illustrate the results for NIRS for participant S1 as a typical example (Figs. 3 and 4). However, the LF/HF (level of sympathetic nerve activity, calculated by monitoring an electrocardiogram (ECG)) during the rest time after the task, tended to be lower for 4K content than for 2K content (Fig. 5). There was a significant difference between LF/HF for 2K content during the rest time before the task and that during the searching task, and between LF/HF for 2K content during the rest time before the task and that during the rest time after the task (Fig. 5). However there was no significant difference between LF/HF for 4K content during the rest time before the task and that during the searching task, or between LF/HF for 4K content during the rest time before the task and that during the rest time after the task (Fig. 5).

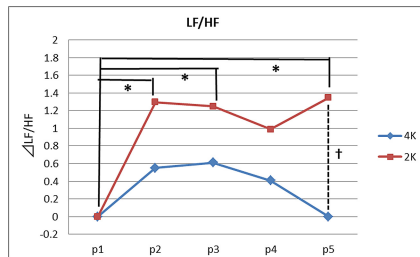
Moreover, HF/(LF + HF) (level of parasympathetic nerve activity) was significantly higher for 4K content than for 2K content during the rest time after the task (Fig. 6). There was a significant difference between HF/(LF + HF) for 2K content during the rest time before the task and that during the searching task, and between HF/(LF + HF) for 2K content during the rest time before the task and that during the rest time after the task (Fig. 6) However, there was no significant difference between HF/(LF + HF) for 4K content during the rest time before the task and that during the searching task, and between HF/(LF + HF) for 4K content during the rest time before the task and that during the rest time after the task (Fig. 6). On the other hand, no significant differences were observed in subjective assessments between 4K and 2K displays. Furthermore, no significant differences were observed in task performance (rate of correct answers) between 4K and 2K displays.



**Fig. 3.** NIRS (O<sub>2</sub>Hb) at 4K and 2K for participant S1. X-axis: resolution (4K or 2K); Y-axis: NIRS (O<sub>2</sub>Hb). (Color figure online)

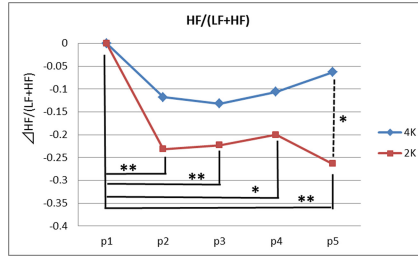


**Fig. 4.** Time course of NIRS (O<sub>2</sub>Hb) during searching tests at 4K and 2K for participant S1. X-axis: Time (sec); Y-axis: NIRS (O<sub>2</sub>Hb). (Color figure online)



**Fig. 5.** LF/HF during searching tests at 4K and 2K (Average value of eight participants). +:  $p < 0.1$ , \*:  $p < 0.05$ ; X-axis: Time (period; p1, p2, p3, p4, p5); p1 = rest time before task; p2 = first half of searching task; p3 = second half of searching task; p4 = first half of rest time after task; p5 = second half of rest time after task; Y-axis: LF/HF

In summary, the NIRS and LF/HF data on use of a 4K tablet for searching tasks agreed with our prior study results on viewing content [1]. The current results suggest that searching tasks at 4K can cause a surge in brain activity but a lower task workload, such as physical and mental stress, although subjective assessments might not exactly mirror the scientific data. Further investigations will be needed to gain a more precise picture of the influence on psychological state of high-resolution 4K displays.



**Fig. 6.** HF/(LF + HF) during searching tests at 4K and 2K (Average value of eight participants). \*:  $p < 0.05$ , \*\*:  $p < 0.01$ ; X-axis: Time (period; p1, p2, p3, p4, p5); p1 = rest time before task; p2 = first half of searching task; p3 = second half of searching task; p4 = first half of rest time after task; p5 = second half of rest time after task; Y-axis: HF/(LF + HF)

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