Optimization of information presentation position in a spectacle-type device considering subject awareness and minimizing discomfort to alerts presented

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**Practitioner Summary:** In this study, we experimentally verify the optimal position for information presentation using a passive reference device. Passive reference information is easily disregarded when presented outside a subject's FOV but is disconcerting when presented close to it. Therefore, we identify the position at which information will alert users, while minimizing discomfort (such as surprise). We also propose design requirements for such a spectacle-type device.

**Keywords:** Spectacle-type Device, Attention, Field of view.

1. **Introduction & Aim**

With the recent expansion of the mobile terminal market, practical application of spectacle-type terminals is being researched and developed. In the work place, in particular, monocular see-through terminals that can be used for information reference and that does not block the actual field of view are already available in the market. Products designed for information acquisition using a spectacle-type terminal can be divided into two types. With one type, it is possible to continuously provide information, such as that in a manual, to the user for “active reference” at any time. The other “passive reference” type presents information in the form of alerts at various times to the user.

Previous studies have focused on the use of “active reference” information and have experimentally studied optimal information presentation positions. For the continuous presentation of information by “active reference,” the information being presented may be difficult to read. However, as the distance from the center of the field of view decreases, the overall visibility of the field of view can get disturbed. Previous studies have also clarified the optimal presentation position as 0° from the center of the visual field in the vertical and 15° to the left or right (Yokoyama et al., 2014).

In this study, the latest in a series, we use “passive reference” information to experimentally examine the optimal information presentation position. If the information that requires attention is unexpectedly presented in the “passive reference” information presentation position, it is more difficult to notice the farther it is located from the center of the field of view. When the information presentation position is closer to the center of the field of view, it can cause surprise and discomfort. In this study, we experimentally investigated presentation positions to determine the positions that caused less surprise or discomfort from information alerts, while also ensuring that users can securely view the presented information. Based on our results, we have proposed a design requirement for spectacle-type terminals.

2. **Method**

2.1 **Experimental Task**

The following experiment was performed by subjects who referred to information displayed on a head mounted display (HMD). First, the subjects were seated in front of a 23-inch display (Diamond Crysta RDT 23IWM, Mitsubishi). Using their normal vision, they were requested to track an object that was moving across the display with a three-dimensional (3D) input device (Phantom Omni, 3D Incorporated). Among 6 objects randomly moving across the display, the subjects tracked objects of specified colors and shapes using 3D directions. Fig. 1 illustrates a typical display viewed by subjects during the task and shows the elements that the subjects controlled with their 3D input devices. The subjects were required to keep the tip of the operating element at the center of the tracked object. The 6 objects were of different colors (green, yellow, white, and red) and shapes (sphere, cube, and cone). Fig. 2 shows an example of a word displayed by the HMD during the tracking tasks. In this case, the subject directed the 3D input device, switching the HMD screen to the next object specified, as shown in Fig. 3, and then continued the tracking. The font size, selected based on the results of a previous study (Tanuma et al., 2012), was 0°25′46″, which could be easily
read by the subjects. The strings comprised 48 symbols describing color and shape combinations, one of which is highlighted in the red frame in Fig. 3. The sequence and highlighted symbol set were changed every 15 s so that the subjects could not remember them during tracking tasks. If the highlighted symbol set was “red Δ,” the subjects recognized the red cone as the next target object. To ascertain that subjects had correctly read the symbol set, they were requested to verbally state the recognized target object. If the target object became lost during a task, the 3D input device was automatically locked. Thus, we could clearly distinguish whether the subjects had conducted the tracking task or had stopped tracking to consult the HMD. In follow-up tasks, the subjects pressed the unlocking button upon reading the symbol set to resume operation. The duration of a single task was 1 min 40 s, with 2 appearances of the word “ALERT.” The subjects were requested to repeatedly interrupt their tracking task, read the information presented by the HMD, and resume tracking. The flow of a single task is shown in Fig. 4.
2.2 Experimental Environment

Fig. 5 shows a schematic of the experimental apparatus and the subjects' arrangement. The viewing distance from the subjects to the 23-inch display (simulating actual field of view) was 100 cm. In addition, to ensure that the center of the subject's visual field matched the center of the display, we adjusted the height of the chair. The viewing angle of the display's information presentation area was 28°34′5″ in the horizontal direction (unilateral 14°30′34″) and 16°17′55″ in the vertical direction (unilateral 8°11′26″), as shown in Fig. 5. The average interior luminance during the experiment was 3.22 lx.

2.3 Participants

Twenty-four visually unimpaired adults (average age: 22.54 ± 1.35 (SD) years; range: 20–25 years) participated in the study. Since all subjects were right-eye dominant (as evaluated with the hole-in-card test), the HMD was mounted on the left side, as suggested in previous studies (Nakanishi et al., 2007).
2.4 Experimental Conditions

Positional information by the HMD was presented in 8 patterns to mimic the information-receiving characteristics of human vision. This information comprised 4 patterns [(15°, 0°), (8°, 0°), (−10°, 0°), (−40°, 0°)] in the vertical direction (Fig. 6) and 3 patterns [(0°, 15°), (0°, 30°), (0°, 50°)] in the horizontal direction (Fig. 7), where the center of the visual field is (0°, 0°). Viewing directions were changed by repositioning the HMD adjuster in the vertical direction and the HMD frame in the horizontal direction. For each condition, the viewing angle of the information presented on the HMD was fixed (at approximately 14°24′ × 10°48′).

![Figure 6. Vertical positions of the presented image](image1)

![Figure 7. Horizontal positions of the presented image](image2)

To properly evaluate the efficiency of the experimental performance and to reduce the effects of the viewing sequence, the experiment proceeded in the following steps (Fig. 8). Prior to an experimental run, the subjects repeatedly practiced the tracking task. We confirmed that increasing proficiency did not alter the performance accuracy. The information was then presented to the subjects at different vertical positions. Each subject performed the task thrice for each of the 5 vertical viewing patterns [the standard condition (0°, 0°) and the 4 vertical patterns described above] in random order. To offset the order effect, the random order of the 5 viewing patterns was varied in each of the 3 trials. The above procedure was then repeated for the 4 horizontal viewing patterns [the standard condition (0°, 0°) and the 3 horizontal patterns described above]. To offset the order effect, we counter balanced the 24 subjects and specified a trial order. In this way, the effect of ordering was corrected in the horizontal and vertical directions, although an order effect may have been introduced by viewing from left to right or vice versa. Therefore, we also incorporated the standard condition (0°, 0°), which alters the position of information presented in both vertical and horizontal directions, to provide a reference during analysis.
2.5 Measurements
First, as an index of the subjects’ likeliness to notice the word “ALERT” displayed by the HMD, we measured the elapsed time from when the word “ALERT” appeared until the subject pressed the 3D input device. More specifically, we measured the time from the operation of the automatic lock after the (n-1)th screen was switched by pressing the 3D input device to the nth time the subject pressed the unlock button to continue tracking. The measured time included the processing time of the HMD, although these times are considered to be identical in every experiment. Second, as an index of discomfort, we measured the subject’s electrodermal activity and heart rate for 10 s after “ALERT” appeared. These two indices were normalized in the individuals.

2.6 Ethics
All participants provided their informed consent. Data were encrypted to prevent identification.

3. Result
3.1 Likeliness to notice the alert
We compared the time of notice, i.e., the time a subject takes to notice the alert presented by the HMD, for each information presentation position. Fig. 8 shows the time of notice for the horizontal positions, and Fig. 9 shows the time of notice for the vertical positions. Our results show that the time of notice for the horizontal position (0°, 50°) was significantly different from that of other positions. In the vertical position (−40°, 0°), the time of notice was significantly different from that of other positions. From these results, we observe that as the information presentation position moves further away from the center of the field of view, the time of notice increases, thus supporting our hypothesis.

3.2 Discomfort from the alert
We then compared the average electrodermal activity with the average heart rate as indicators measuring discomfort due to the alert shown in the HMD. Figs. 10 and 11 show the relationships of the average electrodermal activity against the vertical and horizontal positions of the HMD. Figs. 12 and 13 show the relationships of the average heart rate against the vertical and horizontal position of the HMD. In Figs. 10

![Figure 8. Time of notice of HMD information presented at different horizontal angles](image)

![Figure 9. Time of notice of HMD information presented at different vertical angles](image)
and 12, there is little difference in the average electrodermal activity between (0°, °) and (0°, 30°) in the horizontal position. On the other hand, there is a significant decrease in the average heart rate at (0°, 30°), as compared with that at (0°, 0°), as shown in Figs. 11 and 13. The electrodermal activity is an indicator of “the sweat gland activity controlled by the sympathetic nerve.” (Ogata et al., 1992) The heart rate is an indicator of “the sympathetic nerve increasing the heart rate but the parasympathetic decreasing the heart rate.” (Fuji, 2008) Our results clearly indicate that the subjects were influenced by the parasympathetic nerves during the experiment. It is said that “the parasympathetic nervous system works in comfortable conditions and the sympathetic nervous system works for the first time when a subject is under stress such as being nervous or excited.” (Muto et al., 2011) Therefore, we consider that there is a marked difference in comfort between the (0°, 0°) and (0°, 30°) positions with respect to the passive reference position. Positioning the image at the center of the field of view may be the main cause of discomfort to the subject.

Figure 10. Average electrodermal activity associated with the HMD information presented at different horizontal angles

Figure 11. Average electrodermal activity associated with the HMD information presented at different vertical angles

Figure 12. Average heart rate associated with the HMD information presented at different horizontal angles
Figure 13. Average heart rate associated with the HMD information presented at different vertical angles

4. Investigation of the optimal position of the information presented in passive reference

The previous section analyzed the complexity of the visual field and the referencing efficiency of users glancing at an HMD. The existence of a trade-off between referencing efficiency and viewing complexity was suggested, but it was not confirmed. Therefore, we next incorporated both factors into a total evaluation index and attempted to comprehensively determine the optimal position for presenting HMD information.

First, as mentioned in section 2.4, our experimental procedure could not exclude the possibility of an order effect between left–right and up–down viewings of the presented information. Therefore, the reference condition (0°, 0°) was incorporated in both horizontal and vertical viewing patterns. Here, we examine whether the order effect exists and, if present, to what extent it influences the outcome. To this end, we assumed that differences under the same conditions may be completely ascribed to the order effect, and we can subtract the difference from the results obtained at each horizontal position of information presented. The corrected values are given by the following equation:

\[ V_{each} + h0 - V0 = newVn, \]

where \( V_{each} \) and \( newVn \) denote the complete and corrected data, respectively, in the vertical direction. \( Vn \) and \( h n \) are the average values of \( n \) data in the vertical and horizontal directions, respectively, and \( Sall \) is the standard deviation of all data (corrected by the vertical data).

The corrected data were then normalized as follows. The field-of-view complexity index and the referencing efficiency were scaled using the standard condition (0°, 0°):

\[ h0 - x0 / Sall = newxn, \]

where \( xn \) and \( newxn \) are the complete and corrected data, respectively.

Following the above procedures, we obtained the weighted sum of 1:1 for the field-of-view likeliness to notice the alert and the discomfort experienced from the alert. We defined the value obtained by inverting the sign index value when the value increases as the total evaluation index, in consideration of both sides. Figure 14 shows the total evaluation index at each position of the presented information. The highest evaluation was obtained at (0°, 30°), and at (0°, 50°) and (−40°, 0°), which are significantly far from the center of the visual field, the evaluation indexes were low. From these results, we infer that the discomfort from the alert is mitigated without compromising its likeliness to notify when the HMD is horizontally positioned at 30° from the center of the visual field (0°, 0°). This result suggests that an optimal position exists on an HMD for presenting information that can be rapidly accessed by workers.
Figure 14. Evaluation index computed for each position of information presentation

5. Conclusions

Assuming that an HMD is available for “passive reference,” we have focused on the likeliness to notice the alert and the discomfort experienced from the alert. We expect that a trade-off exists between these 2 factors. Therefore, we experimentally determined the optimal position for presenting HMD information that mitigates the complexity of the visual field, while preserving performance accuracy. The optimal position was found to be intermediate between the periphery and center of the visual field. Specifically, a horizontal shift of 30° from the center of the visual field yielded the highest evaluation score. As mentioned in the introduction, passive referencing of continuously accessible information is a distinct advantage of monocular see-through terminals in industrial applications. The results of this study could be adopted as a guideline for terminal designs. However, our approach requires further development. When constructing a comprehensive evaluation index of the field-of-view likeliness to notice the alert and the discomfort experienced from the alert, we equally weighed both factors. This weighing may change with the perceived importance of the visual target and the viewing frequency. The weighing of ancillary information may also depend on the actual field of view. The appropriateness of defining optimal positions for information presentation will form part of our developmental research.

References


