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Evaluation of Attention Guidance through Visual Subthreshold Stimulus Using a HMD

Yusuke Maeda[1], Keiichi Watanuk[1,2], and Kazunori Kaede[1,2]

[1]Graduate School of Science and Engineering, Saitama University, 255 Shimo-okubo, Sakura-ku, Saitama-shi, Saitama 338-8570, Japan
[2]Advanced Institute of Innovative Technology, Saitama University, 255 Shimo-okubo, Sakura-ku, Saitama-shi, Saitama 338-8570, Japan

ABSTRACT

In recent years, the demand for virtual reality has been increasing due to the expansion of the virtual reality market, but because of the high degree of freedom, there is a possibility that the direction of attention may be dispersed. This study evaluates the attention inducing effect of a visual subthreshold stimulus inserted with brief darkening as a masking stimulus that does not impair the sense of immersion. We hypothesize that the location, duration, and size of the stimulus, as well as the contrast ratio of the brightness between the stimulus and masked stimulus, are factors that contribute to the perception of the stimulus, and aim to investigate effective attention guidance through a visual subthreshold stimulus. We use the reaction time of a visual search task and the presence/absence of perception of the stimulus to evaluate the attention guidance effect and analyze the factors for stimulus perception. Experiments results demonstrate that the visual subthreshold stimulus induces attention; however, the stimulus presentation time, contrast ratio of the brightness between the stimulus and masked stimulus, and the size of the stimulus have significant effect on stimulus perception.

Keywords: Subthreshold stimulus, Subthreshold perception, Attention, Virtual reality

INTRODUCTION

In recent years, the virtual reality (VR) market has expanded, and the number of contents is expected to increase. VR allows users to enter a virtual space by wearing a head-mounted display (HMD); however, owing to its characteristics, user attention is dispersed, and users do not always pay attention to what the content creators want them to see. For example, in 360° images such as VRCG animations, it is possible for the HMD wearer to decide the gaze direction, and attention may not be fixed in one direction alone. Therefore, if the HMD wearer's attention is explicitly guided in one direction, the immersion may be degraded. In "Invasion!", a VRCG animation produced by Baobab Studios, attention is guided by the gaze of a character using the gaze cue effect (Friesen and Kingstone, 2003). Besides, there are other methods that use subthreshold stimuli to naturally guide the attention

of the information receiver. In particular, attention guidance using visual subthreshold stimuli suggests that the insertion of a brief blinking stimulus in a masked image before a visual search task with top-down attention can produce an attention guidance effect (Prasad and Mishra, 2019). However, attentional guidance by practical visual subthreshold stimulus has not been investigated, and there are no studies using them for VR.

In this study, we evaluate the attention guidance effect of a visual subthreshold stimulus while wearing a head-mounted display (HMD). We explore a method for effectively presenting visual subthreshold stimuli in VR. We perform an experiment in which we utilize a darkening called blink inserted in the teleportation used for movement in VR as a masked stimulus, insert a visual subthreshold stimulus, and record the subsequent gaze information and reaction time of the visual search task. We use the recorded gaze information, reaction time, and stimulus perception feedback from the participants in the experiment to evaluate the attention guidance through visual subthreshold stimulus.

ATTENTION GUIDANCE EVALUATION EXPERIMENT

Experiment on Attention Induction through Visual Subthreshold Stimulus

In this experiment, part of a search object in a visual search task is presented as a visual subthreshold stimulus to investigate whether attention is guided in a direction (Higuchi, Inoue, Endo and Kumada, 2019). The participants wore HMDs and viewed the images by moving their gaze. After 2 s of gazing, a 0.3-s dark period was shown, during which a visual subthreshold stimulus could be inserted. The presentation method for the stimuli is shown in Figure 1 and the video sequence is shown in Figure 2. The participant was required to find an object with a tilted stripe pattern among eight objects in a visual search task after the dark period and determine the direction of the tilt. The participants were 10 people who provided informed consent.

The mean value and standard deviation of the reaction time of all the participants under each condition are shown in Figure 3. In the figure, "match" denotes the appearance of the visual subthreshold stimulus and target at the same location, "nonmatch" denotes the appearance of the target at the same location as the distractor, and "neutral" denotes the case where the subthreshold stimulus is not presented. The angle between the visual subthreshold stimulus at the gazing point and the point at which the viewpoint exceeds the 50° viewing angle for the first time are depicted in Figure 4.

The resultant graphs show that there is no significant difference among the three conditions; however, the number of times the participants move their gaze in the direction of the visual subthreshold stimulus is the highest. This indicates that the visual subthreshold stimulus induces gazing. However, some of the participants perceived the stimulus. Because the stimulus used in this experiment contains white (#FFFFFF) in contrast to black (#000000), the contrast ratio between the color of the masked stimulus and that of the stimulus is high, which may have reduced the perceptual difficulty.

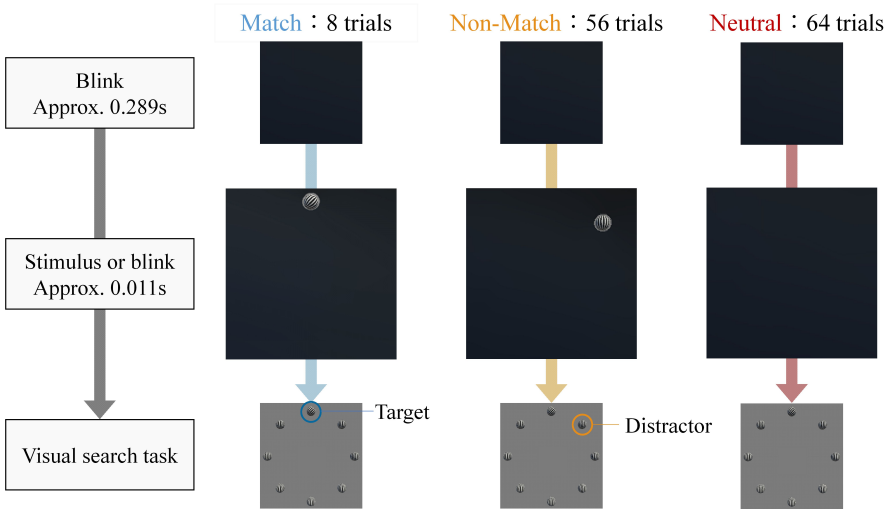

Figure 1: Visual subthreshold stimulus presentation method.

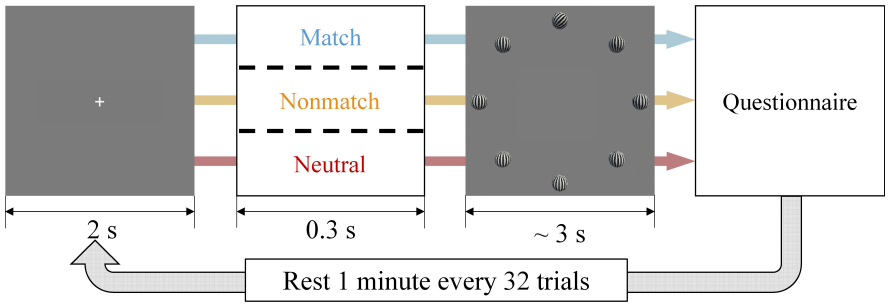

Figure 2: Video presentation sequence.

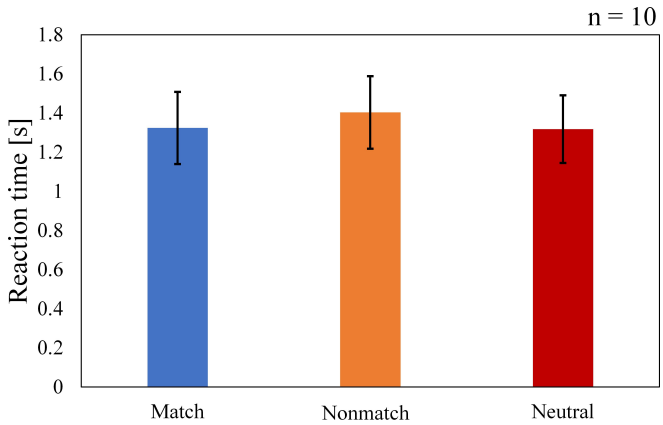

Figure 3: Reaction time of all the subjects under each condition.

Experiment on Attentional Induction through Visual Subthreshold Stimulus Considering the Stimulus Intensity

In this experiment, the stimulus is presented as a visual subthreshold stimulus using different presentation methods, color brightness, and size in either the

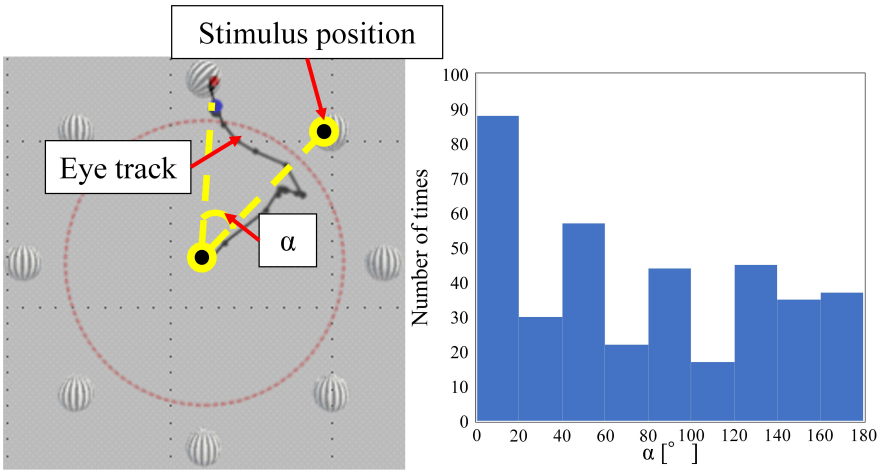

Figure 4: Number of times the stimulus is perceived by all the participants under each condition.

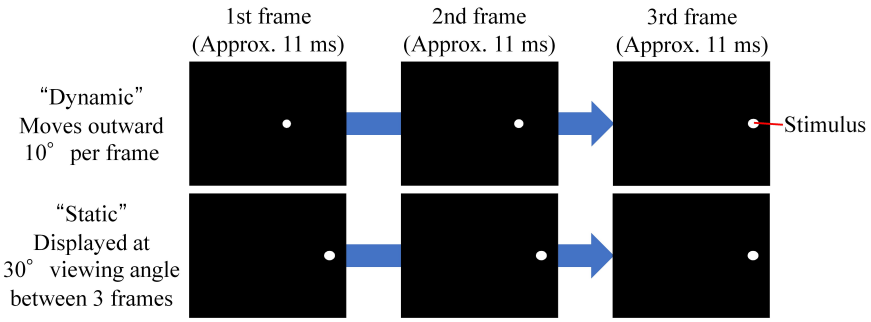

Figure 5: Stimulus presentation method.

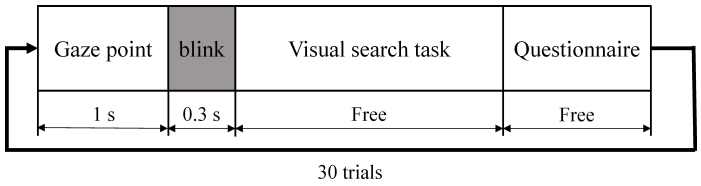

Figure 6: Video presentation sequence.

left or right direction to determine whether the attention direction is guided. The presentation method for the stimuli is shown in Figure 5 and the video sequence is shown in Figure 6. The participants wore HMDs and watched images by moving their heads and gaze. After 1-s of gazing, a blackout of 0.3 s was presented, during which a subthreshold stimulus could be inserted. The participant was required to find an object with a tilted stripe pattern among two objects in a visual search task after the dark period and determine the direction of the tilt. The participants were 10 people who provided informed consent.

The mean value and standard deviation of the reaction time of all the participants under each condition are shown in Figure 7. The conditioning of

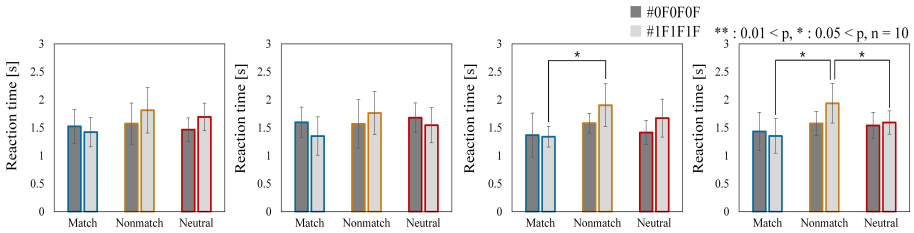

Figure 7: Reaction time of all the subjects under each condition.

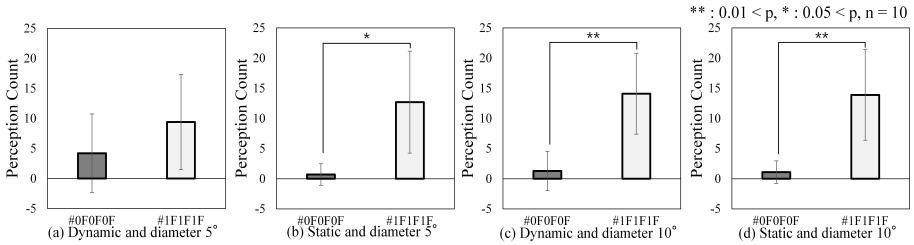

Figure 8: Number of times the stimulus is perceived by all the participants under each condition.

the reaction time is the same as that of the previous experiment. The mean and standard deviation of the number of times the stimulus is perceived by all the subjects under each condition are depicted in Figure 8.

The resultant graphs show that there is a significant difference when the brightness of the stimulus color is (#1F1F1F) with a size of 10°. However, the number of times the stimulus is perceived increases when the color brightness is (#1F1F1F), suggesting that the explicit stimulus may have induced an attention effect. In addition, the effect of the contrast ratio of the color brightness on the masking stimulus may be the maximum in stimulus perception.

Experiment on the Discrimination Limits in the Color Brightness

In this experiment, we investigate the extent of the color-discrimination limit of the stimulus against a black (#000000) masked stimulus. The participants were instructed to gaze at the red gazing point and perceive the stimulus in their peripheral vision. We conducted three trials each under two conditions: one in which the stimulus was flashed and flickered for approximately 0.011 s or 0.033 s and the RGB values were increased by one each (up condition), and the other in which the RGB values were reduced by one each (down condition). In the up condition, the RGB values of the stimulus commenced at (0, 0, 0), and when the stimulus blinks were first perceived, the RGB values were obtained and reduced by one. In the down condition, the RGB values were measured when the stimulus blinks were no longer perceived.

The mean and standard deviation of the RGB values of the imperceptible limit at the display position and the stimulus size for all the participants are shown in Figure 9. The mean and standard deviation of the RGB values of the imperceptible limit for the stimulus display time are depicted in Fig. 10.

The resultant graphs show significant differences between the stimulus size and display time conditions. However, there is no significant difference

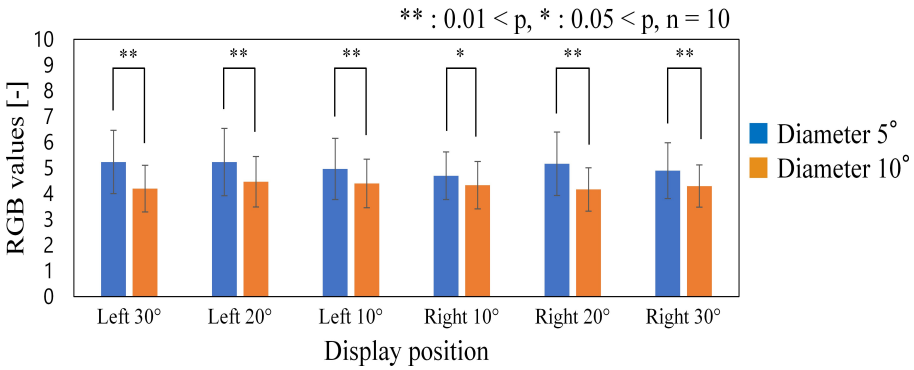

Figure 9: RGB values of the imperceptible limit at the display position and the stimulus size.

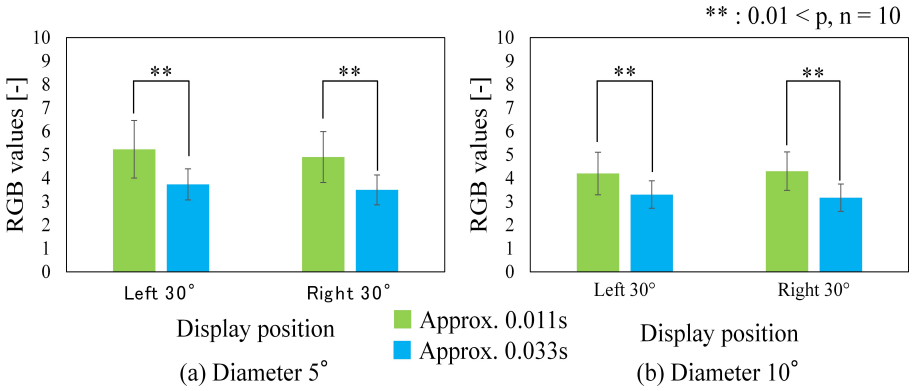

Figure 10: RGB values of the imperceptible limit of the stimulus display time.

between the stimulus position conditions. The mean size of the RGB values at the imperceptible limit suggests that the factors affecting the stimulus intensity are the display duration, size, and position in that order.

CONCLUSION

In this study, we used visual subthreshold stimuli such as a teleportation blink, which is a means of transportation in VR, and blink darkening as a masked stimulus to evaluate the effect of attention guidance through visual subthreshold stimulus and to consider the factors that change the difficulty of perception. Experimental results demonstrated that the visual subthreshold stimulus was effective in inducing attention. Moreover, the results indicated that the perceptual difficulty of a stimulus presented for a short duration did not depend on the position of the stimulus but on the size and duration of the stimulus in a 60° viewing angle. In future, we intend to evaluate the usefulness of this system by setting the stimulus intensity to the limit that can be perceived by an HMD wearer.

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