Present Information Through Afterimage with Eyes Closed

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ABSTRACT
We propose a display method using the afterimage effect to illustrate images, so that people can perceive the images with their eyes closed. Afterimage effect is an everyday phenomenon that we often experienced and it is commonly utilized in many practical situations such as in movie creation. However, many of us are not aware of it. We strongly believe that this afterimage effect is an interesting phenomenon to display information to the users. We conducted an experiment to compare the duration of the afterimage effect to the duration of participant exposure to the image projection. We also prototyped a wearable type display to give more flexibility and mobility to our proposal. With this, one can utilize this method for various applications such as to confirm password at a bank etc.

Categories and Subject Descriptors
H.5.m [**Information Interfaces and Presentation (e.g. HCI)**]: Miscellaneous.

General Terms
Design, Human Factors.

Keywords
Blink, Display, Afterimage effect

1. INTRODUCTION
Normally, we see with our eyes open. However, there is an interesting phenomenon which enable use to see with our eyes close. When a bright light is shone to the eyes for a short period of time, the image portrayed in the light will remain in the eyes even once the light is removed. This is an optical illusion known as the afterimage effect [14]. This effect occurs because the receptor cell in the eye does not have the capability to react instantaneously to the illumination changes [14]. The image can be perceived both when the eyes are open and close, but the image would be much clearer with the eyes close. The reason for this is that when the eyes are closed, there is no external lights that will overlap the afterimages observed, but when the eyes are open, the eyes will start adapting to other external lights entering the eyes. We focused on utilizing this phenomenon to display information with the eyes closed. This effect is commonly experienced in our daily lives. For example, when we briefly look at the sun or when we see the headlights of a car at night [1]. However, in normal viewing, when our eyes are always moving, the view is constantly changing. Therefore, the afterimages will get mixed in the visual shuffle. Thus, we hardly take notice of it [4].

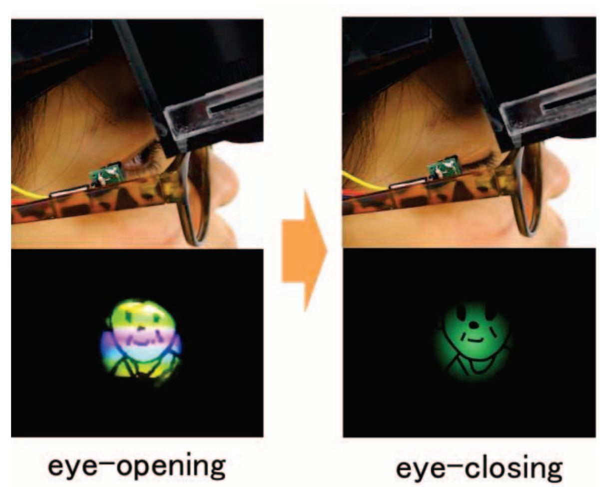

Figure 1: The flash light leaves afterimage when eyes are closed

In the past, this effect has often been used in imaging technologies. For example, to determine the number of frames assigned in films. In recent years, there are many proposed methods on utilizing this effect as an information display. A common one is to utilize saccade movement of the eyes. Rekimoto et al. created a prototype of a digital micro-mirror projector by removing the color filter and having only a single light source – projecting light patterns of uniform brightness and uniform flicker frequency but of a different flicker phase, to create a temporal phase shift illusion. He found out that the boundaries of the patterns are still noticeable when the eyes move, even though the projector flickering frequency is higher than the critical flicker frequency. He also proposed the ability to use this principle to create an interactive system [13]. Ando et al. proposed a display system utilizing precise saccade detection techniques and the perceptual features of the eye movements [2]. For the case of saccade phenomenon, the images can only be observed when the eyes are moving. As compare, our suggested method will be able to sustain the images for a longer period of time when the eyes are closed.

Afterimage effect has also been utilized in many practical situations, such as for creative art showcases or branding purposes etc. Grinder-man did a performance known as Lightly-Light, where small square boxes are placed on the chest of the performers [6]. The performers will stand in front of the audiences and light from within the boxes will be projected to the audiences. A heart-shaped afterimage will remain in the audience perception. In terms of branding, BMW produced an innovative promotion video, Flash Projection, utilizing this effect by featuring their logo at the end of the video just before the audience close their eyes. Many of the audience were impressed with the afterimage of the logo left in their sight [3].

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Our proposed method has similarities whereby we utilize this afterimage effect to display cohesive information in our eyes. As this effect has interesting capabilities, we would like to explore into its features and apply this method into different scenes to create a more interactive information display. In this paper, we introduced various applications where this method may be applicable. We also created a prototype of our system in the form of a wearable afterimage display, where it has the potential to widen its usage due to its mobility.

2. IMPLEMENTATION

2.1 Experiment

We conducted an experiment to observe the co-relation between the duration of how long the afterimage will last in the participant's perception with the duration of how long the participant was exposed to the light source. This experiment was conducted in two conditions; in a bright environment and a dark environment. Figure 2 illustrates the apparatus used in the experiment, consisting of a projector (Optoma PK320Pocket Projector), a convex lens (Canon EF50mm f/1.8 II) and a chin support. A filter (Marumi Filter Co. Ltd NEO MC-ND8) is attached to the convex lens to control the amount of light passing through it. As the projection area is relatively large, a plank with a 0.5mm pinhole was placed in front of the projector. The projector will project the image, through the pinhole and then through the convex lens. It will then be projected into the participant's eye. The participant's chin was supported by a chin support to prevent the participant from moving. The procedure of the experiment is as follows:

1) An image illustrated on Figure 3 was projected to the participant's eye for 20ms.
2) The participant will then close her eye. She will open her eyes again when she could not recognize the afterimage.
3) The timing taken until the image has disappeared was recorded.
4) Steps 1-3 were repeated for different time intervals: 50ms, 100ms, 200ms, 300ms, 400ms, 500ms and 750ms.
5) Each experiment were repeated three times and the average results were recorded.

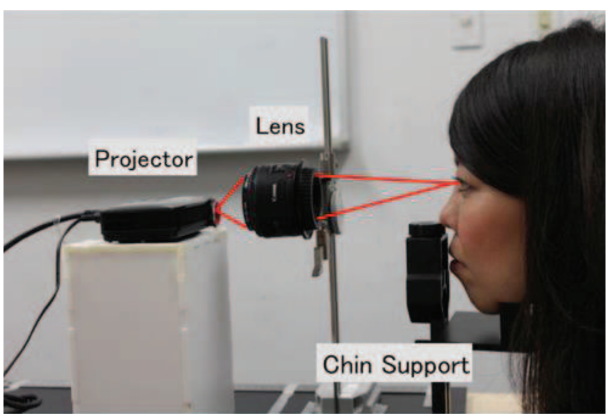

Figure 2: Experiment set up

Figure 3: Retinal image

Table 1: Experiment conditions

Conditions	Bright Environment	Dark Environment
Illumination intensity of light source, K	614[lx]	20[lx]
Distance from focus point to illuminator, D	0.22[m]	0.22[m]
Retinal illuminance	29717600[Td]	968000[Td]
Retinal Image (Background color)	black (#000000) 960x720	black (#000000) 960x720
Retinal Image (Specimen color)	white (#ffffff)	white (#ffffff)

Table 1 elaborates on the experiment conditions. The retinal illuminance [15], which indicates the amount of light falling into the retina, is calculated with the following formula:-

$$e = 10^6 \; x \; K \; x \; D^2 (TD)$$

whereby D is the distance from the focus point to an illuminometer and K is the illumination intensity of light source.

Figure 4 illustrates the results of the experiment. Here, we can observe that when the image is shone to the eyes for a longer period of time; the afterimage will last longer in the observer's perception when her eyes are closed. We can also observe that the afterimage will last longer in the darker environment as opposed to a brighter environment. This is because the human eye can easily adapt to the environment when the amount of visible light in the surrounding is less. When this occurs, the amount of light entering the pupil will increase causing a stronger stimulation to the eye.

We also obtained some feedbacks from the participant. The participant mentioned that the afterimage started off as white and slowly changed into green color. However, after the image started fading away, and when she started opening her eyes, she mentioned that the image color has inversed. From these, we can observed that changing the irradiation time of the information display according to the type of application proposed can increase the effectiveness of the application.

Generally, an average time of a single blink is said to be about 100-400 milliseconds [12]. The experiment results indicate that a content that can be displayed in a blink is about 10-20 seconds in a bright environment and about 12-24 seconds in a dark

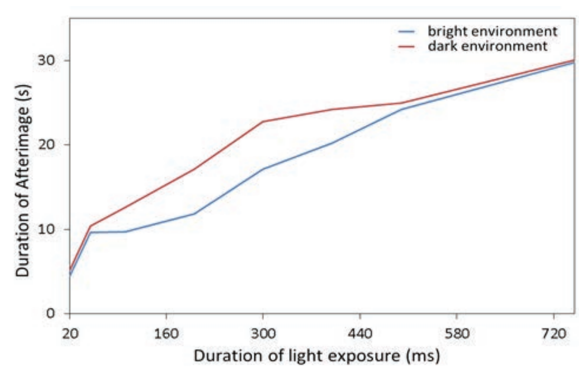

Figure 4: Experiment results

environment. Previous research showed that it only takes about 380 milliseconds for one to be able to recognize a familiar face [11]. This shows that there is plenty of time to display the contents with our method. In addition, Derryberry reported that human can easily recognize letter within 100 milliseconds [5]. This shows that there is enough time to display the contents to users for applications that may require the user's attention.

2.2 Wearable System

We have also prototyped a wearable afterimage display device to test out different applications that can utilize this effect. Figure 5 illustrates the principle of the device while Figure 6 illustrates the device itself. For the device, we utilize the similar projector, plant and lens used in the experiment in combination with a half-mirror and a photo reflector sensor (RPR-220). Compare to the experiment, instead of shining the image straight into the eyes from the lens, the projection from the lens will be reflected on the half-mirror and then into the eyes. The photoreflective sensor is fixed right beside the eyes and is used to detect the blink of the eye by sensing when the eyelid or eyelash get close to the sensor.

This project utilizes a see-through type display using Maxwell's optical system to maintain a normal field of view and to provide as an information display device [7]. This method can project clear image directly to the retina without adjusting the amount of crystalline lens. The implementation of the current prototype is mounted onto a helmet. However, for future works, we aim to create a lighter weight version by miniaturizing the projection apparatus. With this, we can create a display that can display clear images without depending on the wearer's vision or gaze distance.

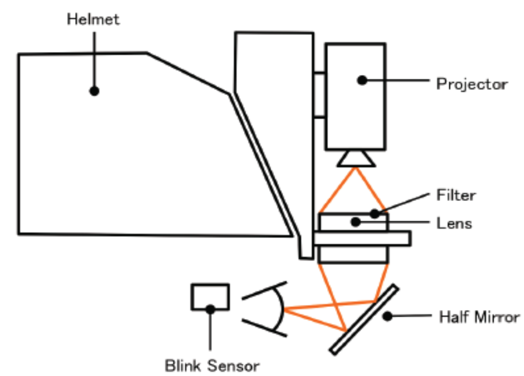

Figure 5: Overview of wearable afterimage display

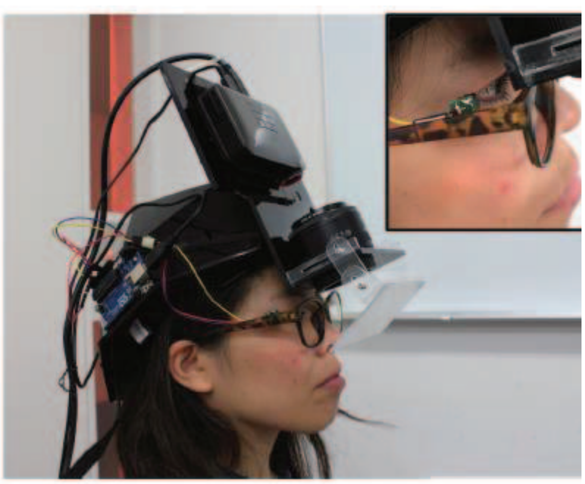

Figure 6: Wearable Afterimage Display Device

3. APPLICATIONS

The results from the experiment shows that different duration of light exposure will cause different duration of afterimage. Utilizing this difference in duration, we can apply this method to different applications that will be described in this section. Reminiscence is common between everyone. However, many people tend to have trouble recalling these past events. This method may give the opportunity for people to be reminded of their past. The picture of the past can be projected to the user (Figure 7). As the afterimage effect is a natural phenomenon, user will be able to be reminded of their memory naturally.

This method can also be used to increase one's attentions or to alert one of information that has been conveyed in advance. For example, to alert someone of the danger in front; this method can be used to display an alert a few seconds before the user reaches the place of caution. With this, the afterimage will faintly remain in the user's perception. When the user reaches the place of caution, and see the danger, they will be reminded of the alert that was displayed a few seconds before. This is similar to the priming effect where human can easily be reminded of something when they were presented with the information beforehand. Isoyama et al. also utilized this effect; they proposed a system that allows user to browse the visual information of their interest during their free time by using a HMD [8].

We also proposed this method to be used as a display to convey private information to only one person or which only requires one person's verification (Figure 8). For example, it can be installed at the bank counter or the cash machine as a type of peeking inside display, to safely verify the personal pin number or to display the one-time password which is widely used in online transactions. Through this, user does not require to memo their password, but instead can utilize this afterimage perception to see their password. With these, we can see the effectiveness of this display method.

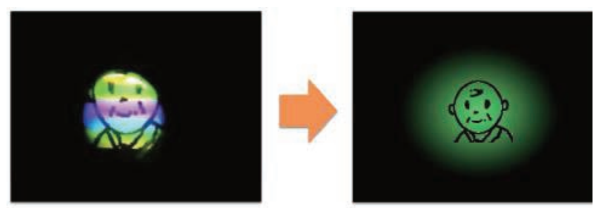

Figure 7: Example of reminiscence

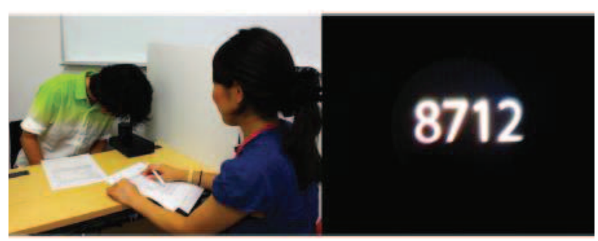

Figure 8: Example to confirm password

4. LIMITATION AND FUTURE WORKS

The current prototype is created to test it capabilities for the proposed applications. However, as mentioned in section 2.3, the current wearable prototype is quite large in size, and is impractical to use in daily life. However, there are many smaller systems in the market and for future development, we aim to design and manufacture a smaller version of the device. Aside from above mentioned shortfalls our prototype can be fastened onto its user.

However, for suggestions such as utilizing at bank counters or cash machines, it may be more feasible to create a fixed version of this device. Besides that, it is dangerous for one to gaze at the light source for long, therefore, the exposure of light must be limited to a short amount of time. From the experiment results shown in Figure 3, a content can be provided between 10 to 24 seconds, just enough for one blink. However, there are difficulties if the content is provided for more than 24 seconds.

5. CONCLUSION

This paper proposed a method to display information when one's eyes are closed by utilizing the afterimage effect. We utilized the Maxwellian optics system to directly project the image into the retina through a pinhole placed in front of the projector. We prototyped a wearable type device to project the image into the user's pupil by focusing the light through a lens to be reflected by a half-mirror and finally into the eyes. Photo reflector sensor is also utilized to measure its distance from the eyelid or eyelash to detect user's blink. There are several applications that can be applied using this proposed method. For example, it can be used to convey information to others such as to be reminded of a past memory or to alert one of a danger ahead. It can also be placed in places such as at the bank counters or ATM machines for user to be able to confirm their own bank pin number. We also conducted an experiment to observe how the duration of light exposure will affect the duration of the afterimage. From our results, the longer the participant is exposed to the light, the longer it takes before the afterimage disappears. With this, one can design the light exposure according to demand.

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