EVALUATION OF SUPERIMPOSING SELF-SHADOW ON DILATED PUPIL IN TWINKLING EYES INTERFACE

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ABSTRACT
It is known that human affects and emotions are reflected in own eyes. Especially, the eyes with strong affects and emotions look like twinkling. Humans are fascinated and attracted by such twinkling eyes. Therefore, it is expected to examine the elements that fascinate humans and develop social robots for attracting humans by reproducing twinkling eyes using engineering approach. We focused on the reflection of the surface in the eyeball and developed a twinkling eyes interface by superimposing self-shadow on dilated pupils. This interface can express the pupil response and the shade of self-shadow depending on the distance. In this study, an evaluation experiment that combines self-shadow with dilated pupil was conducted. The effectiveness of the developed interface was demonstrated by sensory evaluations.

Keywords: Nonverbal Communication, Human-Robot Interaction, Human Interface, Self-Shadow, Attractiveness

1 INTRODUCTION

As the saying goes, “The eyes are the windows to the soul”, human affects and emotions are reflected in their eyes [1]. People can guess affects and emotions from the impression of human eyes. For example, the metaphor “Eyes are laughing” means that positive emotions can be read from the eyes. The metaphor “Eyes are twinkling” means that the eyes with strong affects and emotions look like twinkling [2]. Humans are attracted to such twinkling eyes [3]. Therefore, by reproducing twinkling eyes using engineering approach, we can understand the elements that attract human and develop attractive robots. We focused on the pupil response during communication and developed a pupil response system that expresses pupil dilation. The effectiveness of the system was demonstrated [4]. In addition, we proposed a method called “twinkling eyes” that focuses on the reflections on the surface of the eyeball and developed an interface that applies the method to the developed pupil response system [5]. This interface can express pupil response and the shade of self-shadow based on the distance to the user.

In this study, we conducted an experiment to evaluate using the twinkling eyes interface and demonstrated that the superimposition the self-shadow on the dilated pupil increases interest and attractiveness towards the interface.

2 TWINKLING EYES INTERFACE

2.1 Twinkling eyes method

This study focuses on the “specular reflection” on the surface of eyeball, which is reflected on the cornea in optical elements. It is known that texture and glossiness can be perceived as the reflections [6]. By expressing the surrounding reflections on the eyeball, it is expected to give an impression that a high specular reflection is generated on the corneal surface. In particular, human-shadows enhance the presence in the physical space and increase self-reference by linking with own behavior [7]. Therefore, the “twinkling eyes” that superimposes human shadows as reflections in the pupil was proposed. Fig.1

shows the core concept of the twinkling eyes method. In addition to the twinkling eyes, it is expected that dilating the pupil can strongly attract human.

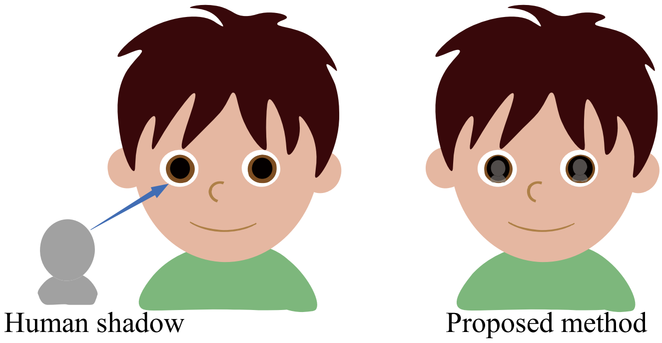

Figure 1. Concept of the twinkling eyes method

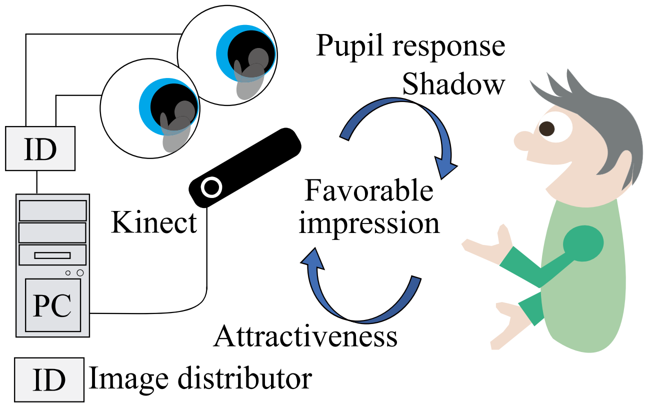

Figure 2. Setup of the twinkling eyes interface

2.2 Developed Interface

An interface that applies the twinkling eyes method to the pupil response system was developed. Fig.2 shows the setup of the developed twinkling eyes interface. The twinkling eyes interface consists of a desktop PC, a motion tracking device (Kinect V2), hemispherical displays, and a video splitter. The iris and pupil, which are components of the eyeball, are drawn as images using OpenCV. A black circle represented as the pupil, and a blue circle is represented as the iris. By changing the size of the black circle, the pupil dilation and contraction are generated. The represented rate of the images is 30 fps.

The flow-chart for generating self-shadows to be superimposed on the pupil is shown in Fig.3. First, the Kinect SDK is used for measuring distance between the user's position and the interface position. Next, the extracted self-contour of the user is converted to gray-scale as a self-shadow. Here, the saliency of the self-shadow could be enhanced by expressing only the self-shadow. Then, by superimposing the user's shadow on the iris and pupil images, it creates a sensation as if the user exists here (Fig.4). The shade and size of the self-shadow can be changed according to the distance between the user's position and the interface position. The position of the user was tracked, and eye contact was realized with each other. The user can easily grasp the own position in physical space between the self-shadow and the interface, and interact while referring to the self-reflected in the eyeball.

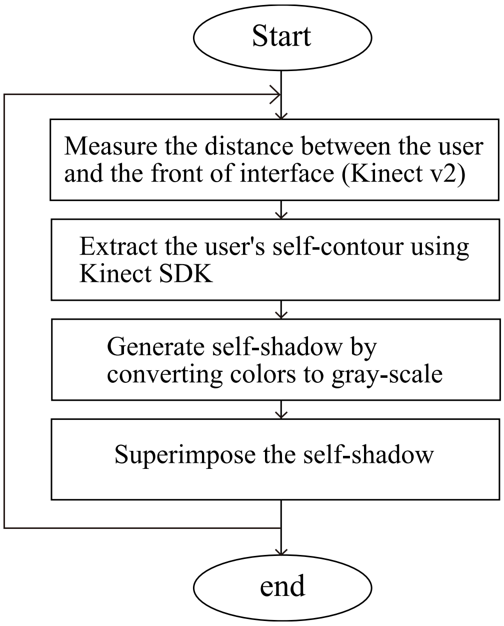

Figure 3. Flow-chart of the generated self-shadow

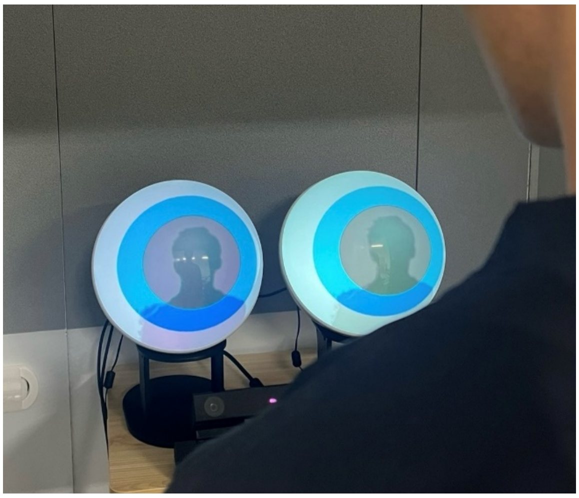

Figure 4. Example scene of using the developed twinkling eyes interface

3 EXPERIMENT

3.1 Experimental method

In this experiment, based on the results of our previous experiment [8], the distance between the participants and the twinkling eyes interface was set to 3m, the shade of shadow was set to 40%. The comparison modes were as follows: (A) Dilation: the pupil size was enlarged to 1.5 times the normal size of pupil diameter, and the shadow was not displayed, (B) Self-shadow: the pupil size was normal, and the shadow was displayed, and (C) Proposal: the pupil size was enlarged to 1.5 times the normal size, and the shadow was displayed.

This experiment was consisting of a paired comparison and a seven-point evaluation for the three modes. In the experiment, the participants were firstly instructed to stand in front the developed interface. Then, they were instructed to perform a paired comparison of modes. In the paired comparison experiment, two modes were randomly selected from three modes, and each mode was presented for ten seconds. They selected their preferred mode based on attractiveness. Finally, after experiencing each mode for ten seconds, they performed an impression evaluation using seven-point scale (nature at four). In this evaluation, following eight items were adopted: “(1) Did you feel like the Robot was gazing you? (Robot gaze)”, “(2) Did you feel attracted to the Interface? (Attraction)”, “(3) Did you feel like the Interface was interested in you? (Interest in oneself)”, “(4) Did you make eye contact with the Interface? (Eye contact)”, “(5) Did you feel trust towards the Interface? (Trust from robot)”, “(6) Did the Interface’s eyes seem to twinkle? (Twinkling)”, “(7) Did you feel a sense of fascination towards the Interface? (Fascination)”, and “(8) Did you want to keep looking at the Interface? (Looking more)”. The presented order of the modes was counterbalanced to consider order effects. The experimental participants were 24 males and females aged 20 to 24.

3.2 Experimental results

The result of the paired comparison is shown in Table 1. In the Table, the number of mode (A)’s winner is twelve to mode (B), and the number of total winners is twenty-two. Fig.5 shows the calculated results of the evaluation provided in Table 1 based on the Bradley–Terry model given in Eq. (1) and (2) [9].

$$P_{ij} = \frac{\pi_i}{\pi_i + \pi_j} \tag{1}$$

$$\sum_i \pi_i = const\,.(= 100) \tag{2}$$

$$\pi_i: Intensity\ of\ i,\ \ P_{ij}: Probability\ of\ judgement\ that\ i\ is\ better\ than\ j$$

Table 1. Result of paired comparison

	(A)	(B)	(C)	Total
(A)		12	10	22
(B)	12		6	18
(C)	14	18		32

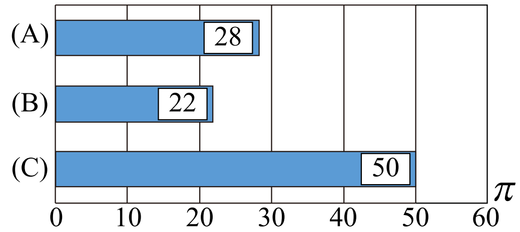

Figure 5. Comparison of π based on the Bradley-Terry model

The consistency of the matching of the modes was confirmed by performing a test of goodness of fit (x^2 (1,0.05) = 3.84 > x_0^2 = 1.04) and likelihood ratio test (x^2 (1,0.05) = 3.84 > x_0^2 = 1.05). The mode (C) was evaluated the most affirmatively, with the mode (A) and the mode (B) following in that order.

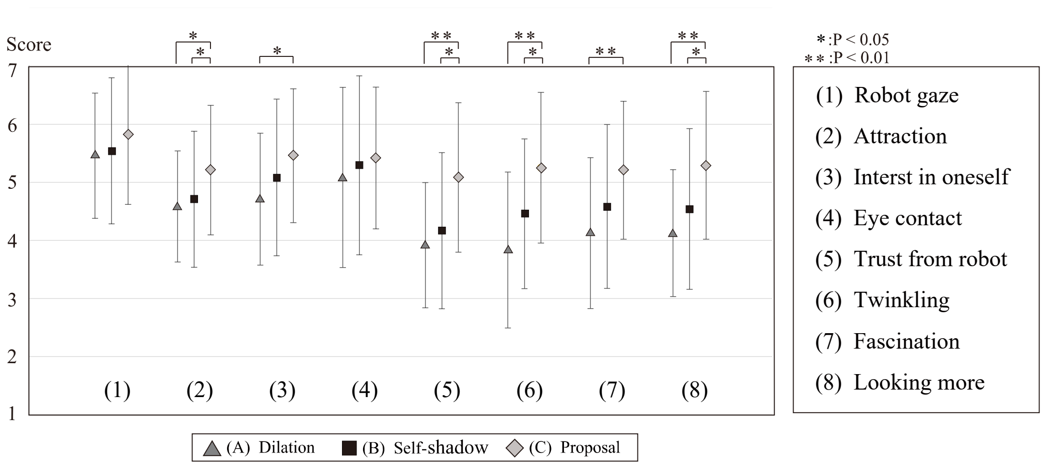

Figure 6. Seven-point evaluation

The questionnaire results are shown in Fig.6. In accordance with the results of the Friedman signed-rank test and the Wilcoxon signed rank test, "(5) Trust from robot," "(6) Twinkling," "(7) Fascination," and "(8) Looking more" were at the significant difference of 1%, "(2) Attraction," and "(3) Interest in oneself" were at 5% between modes (C) and (A). In addition, "(2) Attraction," "(5) Trust from robot," "(6) Twinkling", and "(8) Looking more" were at the significant difference of 5% between modes (C) and (B).

3.3 Discussion

In this study, we evaluated the impression of the twinkling eyes interface, which superimposes self-shadow on the pupil, through paired comparison and a seven-point evaluation. As a result, mode (C), which combined dilated pupil with the self-shadow, was highly evaluated in the paired comparison. In the seven-point evaluation, "(2) Attraction," "(5) Trust from robot," "(6) Twinkling," and "(8) Looking more" were highly evaluated. This is because dilated pupil brought an impression of curiosity [10], which increases interests of the participants in the interface. Additionally, it is considered that the self-shadow was interpreted as objects of the gaze for the interface and a feeling of “seeing/being seen” [11] based on the self-reference [6] was created.

Rousseau defines trust as “a psychological state comprising the intention to accept vulnerability based upon positive expectations of the intentions or behavior of another” [12]. In other words, trust is regarded as a state or feeling that understands and accepts the intentions of others. Applying this definition to the current experiment, it is considered that the mechanism which participant's own behaviors are reflected not only the interface's gaze and pupil size but also the self-shadow made it easier to read interface's intentions. This ease of reading intentions leads to increased trust in the interface. Furthermore, it is considered that the readability of intention is improved even for spatially distant self-shadows by superimposing the pseudo self-shadow on the eyeball rather than presenting it separately [13].

These results indicate the synergistic effects due to pupil dilation and the self-shadow. The effectiveness of the developed interface was demonstrated by sensory evaluations.

4 CONCLUSION

In this study, aiming to elucidate the mechanism of fascinating and attracting human, we evaluated the impression of the twinkling eyes interface, which superimposes the pupil dilation and the self-shadow. The developed interface was highly evaluated through paired comparison and a seven-point evaluation. The effectiveness of the twinkling eyes interface was demonstrated.

In the future, we plan to develop expression methods incorporated into various media, such as applying them to the twinkling eyes of avatars in virtual spaces and verify their effects under various conditions.

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