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Emotional Meaning of Eyelid Positions on a One-Eyed 2D Avatar

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Abstract: Expressing emotions of virtual and robotic agents require complex animations that mimic human behavior. By abstracting the core features in human faces for the emotions described by Ekman, et al., a single-eyed 2D avatar was designed that only moves the upper and lower eyelids. The relationship between how much each eyelid covers the eye and the perceived emotion was evaluated with a within-subjects study with 31 college students. The results showed that it is possible to convey different emotional meanings by changing the eyelids, and adding a white dot to simulate gloss affected the meaning of some emotions considerably. This research contributes to the development of virtual and robotic agents that can show emotions without increasing the complexity of the system, ultimately leading to more natural interactions with artificial systems.
Keywords: *Single-eyed, Emotions, 2D avatar, Minimalist, Interaction*

1. INTRODUCTION

Expressing emotions and giving the illusion of life to inanimate objects have been a common goal for designers, researchers, and engineers alike [1]. In that regard, many researchers have designed robots that can mimic human facial expressions [2–4], but their close resemblance to real human beings make them fall into the Uncanny Valley, the point where their not quite human physical appearance and behavior creates aversion [5].

It has been suggested that a minimalist design can help avoid this aversion [6] and that it is possible to maintain a communication protocol with a minimal design during human-robot interactions [7].

For that reason, the following research aims to study the effects simple eyelid changes of a single-eyed 2D avatar on the emotional meaning being conveyed. The results of a within-subjects experiment revealed that, while it is difficult to associate a concrete category with a specific visual image, it is possible to convey emotional meanings using a simple visual representation of an eye. Also, simulating eye gloss for the same eyelid position affects how the emotion is understood.

The structure of the paper is as follows: Section 2 presents a summary of related works, Section 3 explains the design process of the avatar, Section 4 details the experiment methodology, Section 5 presents the results obtained and their analysis is discussed in Section 6, and Section 7 finishes with the conclusions and future work of this research.

2. LITERATURE REVIEW

Research in social robotics have identified that gaze following is important in recognizing a robot as an agent with its own mind [8]. This mechanism leads to the development of empathic understanding [9] and looking at the eyes of other people helps in understanding emotions [10].

According to Ekman, et al., emotions can be catalogued by Action Units (AU), facial movements that correspond to specific facial muscle, and they identified seven universally recognized emotions that could be understood regardless of culture [11]. Additionally, Faigin created an emotional facial guide for artists based on his studies in visual arts and complemented with the theory of Ekman [12]. The combination of AUs in different ways produces specific shapes and wrinkles in the face that have an emotional meaning and can be understood globally.

2.1 Emotional expressions in artificial agents

Research done about visual design, color, and shape of products has found that the emotional condition of users is affected by those stimuli [13]. A similar research on robot interfaces found that the main stimuli used in

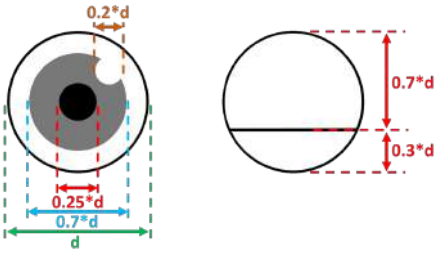

Figure 1: Design and dimensions of the avatar.
Fully opened eye showing the sclera, iris, pupil, and glossy effect (left), and closed eye showing the ratio between the upper and lower eyelids (right).

artificial agents to express emotions are sound, color, and vibrations [14].

2.2 Single-eyed expressions in animation

In the animation and gaming industry, characters with only one eye have been designed and are able to transmit to the audience a wide range of emotions. Some of the common characteristics to these characters are the absence of a brow and a human-like ration of the iris and the sclera [15].

3. DESIGN PROCESS

To allow for gaze following while simplifying the shape of the avatar, a single-eyed round design was developed. This avatar, presented in Figure 1, was composed of three concentric circles. To create a scalable avatar design, all measurements were proportions of the overall diameter of the eye d. The iris was set to grey color (R:120, G:120, B:120) to avoid any bias from colorful stimuli and its diameter to $0.7 * d$. The pupil had a diameter of $0.25 * d$. A glossy texture was simulated by adding a white circle of $0.2 * d$ diameter located at the top right of the eye. To mimic the proportions of a human eye, the upper eyelid covered $0.7 * d$ of the eye, while the bottom eyelid covered the rest. There is no bending of the upper eyelid to imitate the eyebrow muscle to avoid complex animations.

The facial characteristics described by Ekman and Faigin were analyzed, focusing on the main features of the eyes [11, 12]. The seven basic emotions were used as a base to create the different emotional expressions presented in Table 1.

4. METHODOLOGY

To find the relationship between the position of the eyelids and the emotion expressed, a within-subjects

Table 1: Set of emotions based on the physical characteristics of human beings.

Emotion	Description	Expression	Avatar
Neutral	Upper eyelid touches the iris, lower eyelid is relaxed.		
Happy	Cheeks raise, pushing the lower eyelid. Upper eyelid can be raised.		
Surprise	Eyes wide open. Sclera fully visible.		
Sad	Eyes slightly squinted, upper eyelid drops due to the brows.		
Fear	Eyes open and tense. Lower eyelid contracted.		
Disgust	Eyes squinted due to the wrinkle of the nose.		
Anger	Eyes focused and wide open. Upper eyelid seems lower due to the brow.		

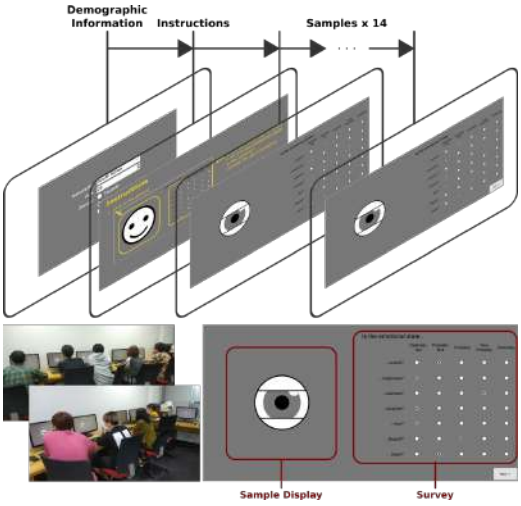

Figure 2: Custom program used to measure emotional appreciation of the avatar.
Participants were presented with three screens: 1) a demographics survey, 2) instructions of the experiment, and 3) 14 sample images displayed in random order.

study was conducted with 31 design students ($11F$, $M_{age} = 25.0$, $SD_{age} = 2.9$) from South Korea. Based on the initial analysis of facial expressions, two sets of pictures were made for each emotion: one with and the other without gloss, for a total of 14 samples.

A 5-point Likert scale for likelihood (1-Definitely Not | 2-Probably Not | 3-Probably | 4-Very Probably | 5-Definitely) was used to measure the confidence level that a specific emotion was being shown by the

avatar. For each sample, the participants had to rate the confidence level that the avatar was displaying a neutral, happy, surprised, sad, fear, disgust, or angry emotion.

To minimize cognitive bias, a custom survey program was developed in Visual Studio 2017 (C#). As presented in Figure 2, first, the participants were asked to fill in their nationality, age, and gender. Then, an instructions screen was presented. The instructions were automated to ensure that every participant received the same information. After that, the 14 samples were presented to the participants in a random order using the Fisher-Yates shuffling algorithm [16, p. 142]. Each sample's questionnaire had to be fully completed to show the next figure, but there was no time limit imposed to answer the questions. All the backgrounds in the program were set to a value of R:120, G:120, B:120 to avoid any bias from different hues. A 1 s gap was added in between each sample to avoid giving the illusion that the avatar had animations.

5. RESULTS

A two-way repeated measures ANOVA, presented Table 2, was conducted using R to analyze the effect of the sample and type of emotion on the emotional likelihood level. There was a statistically significant interaction between the effects of sample and type of emotions on how the meaning was conveyed, $F(78, 2910) = 13.700$, $p =< .0001$. A boxplot of the likelihood values is presented in Figure 3.

A post hoc pairwise comparison with Bonferroni adjustment showed a significant difference between samples *(a)* and *(f-g)* ($p =< .001$) for both with and without gloss. The sample *(a2)* was significantly different from *(b1)* ($p = 0.017$) and *(b2)* ($p = 0.003$). The sample *(e2)* presented a distinction when compared with *(c1)* ($p =< .001$), *(d1)* ($p =< .001$), and samples *(f-g)* ($p =< .001$). The samples *(b)* and *(g)* were also significantly different ($p =< .001$) for both with and without gloss. No significant difference was found between *(f1)*, *(g1)*, *(f2)*, *(g2)* ($p = 1.000$).

6. DISCUSSION

6.1 Mixed emotional states

Some samples of the avatar presented a high likelihood in more than one emotional state, as in the case of *(a2)*, the wide opened eye with gloss [$Surprise = 3.45$, $Happy = 3.06$, $Neutral = 3.29$], *(e1)*, the avatar of fear without gloss [$Surprise = 3.48$, $Fear = 3.32$], and especially the squinted group of eyes *(f1)*, *(g1)*, *(f2)*, *(g2)*, representing disgust and anger. These results are consistent with conclusions drawn by Ekman, in which one shape of eyes can appear in more than emotional state, like the wide open eyes during the emotional blend *surprise-happy* [11, p. 36].

Table 2: Two-Way Repeated Measures ANOVA

Source	df	F-value	p-value
Sample	13	1.860	**0.030***
Emotion	6	44.211	**<.0001***
Sample x Emotion	78	13.700	**<.0001***

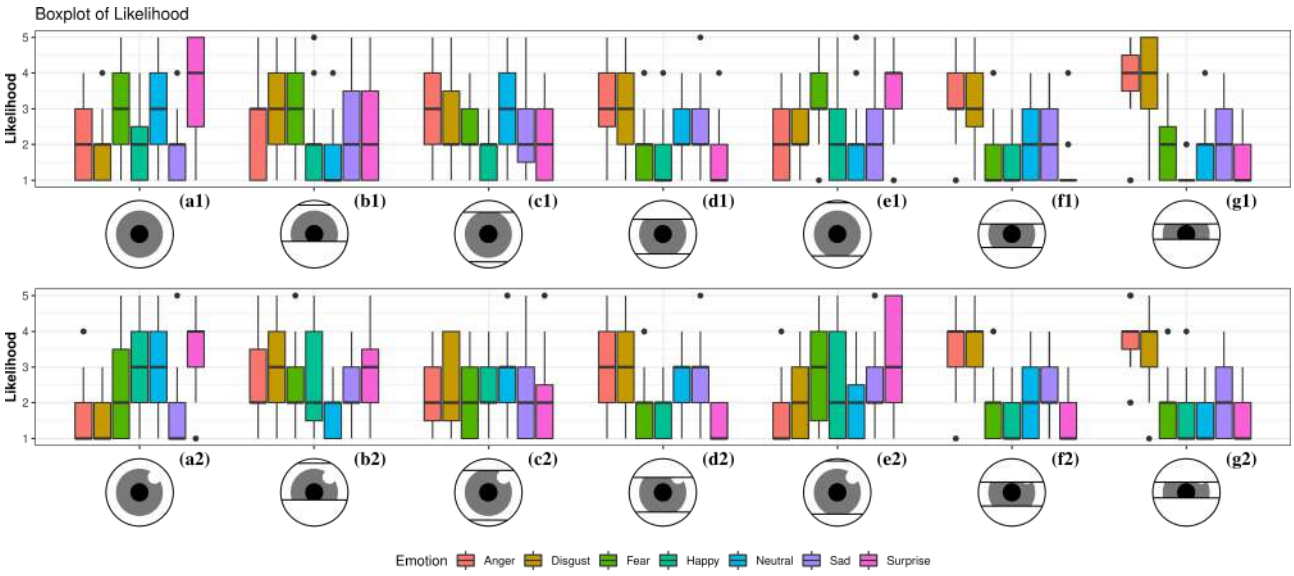

Figure 3: Boxplot of the Emotional Evaluation of Each Sample

6.2 Limitations

The evaluation of this research was done on a 2D display, which disregards the effect that a 3D avatar might produce in physical agents. Furthermore, each sample consisted of static images without any animations. It is possible that the speed in which the eyelids open and close and the movement and dilatation of the pupil affects the emotion conveyed. Finally, the main group of participants were from Asian ethnicity, which may carry a bias on how emotions are expressed and understood for 2D characters.

7. CONCLUSIONS

This research evaluated if it is possible to express different emotions using only one eye with rigid eyelids. The results showed that people understand the difference in emotional states just by changing the positions of the eyelids, while adding or removing the effect of gloss affected the emotional meaning. The authors hope that the contributions of this work allow developers to create artificial systems that can use emotional communication without adding complex mechanisms or interfaces. The results of this research can be applied to minimalist virtual agents to improve consumer electronics and add an emotional layer to the experience.

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REFERENCES

[1] J. Bates, The Role of Emotion in Believable Agents, Communications of the ACM, 37(7), pp. 122–125, 1994.

[2] C. Breazeal, Emotion and Sociable Humanoid Robots, International Journal of Human-Computer Studies, 59(1-2), pp. 119–155, 2003.

[3] S. Nishio, H. Ishiguro, and N. Hagit, *Geminoid: Teleoperated Android of an Existing Person*, A. C. de Pina Filho, Ed., 2007.

[4] T. Kishi, T. Otani, N. Endo, P. Kryczka, K. Hashimoto, K. Nakata, and A. Takanishi, Development of Expressive Robotic Head for Bipedal Humanoid Robot, In: 2012 IEEE/RSJ International Conference on Intelligent Robots and Systems, pp. 4584–4589, Vilamoura-Algarve, Portugal: IEEE, 2012.

[5] M. Mori, K. MacDorman, and N. Kageki, The Uncanny Valley [From the Field], IEEE Robotics & Automation Magazine, 19(2), pp. 98–100, 2012.

[6] H. Sumioka, T. Minato, Y. Matsumoto, P. Salvini, and H. Ishiguro, Design of Human Likeness in HRI from Uncanny Valley to Minimal Design, In: 2013 8th ACM/IEEE International Conference on Human-Robot Interaction (HRI), pp. 433–434, Tokyo, Japan: IEEE, 2013.

[7] K. Youssef and M. Okada, How a Minimally Designed Robot can Help Implicitly Maintain the Communication Protocol, International Journal of Social Robotics, 9(3), pp. 431–448, 2017.

[8] A. N. Meltzoff, R. Brooks, A. P. Shon, and R. P. Rao, "Social" Robots Are Psychological Agents for Infants: A Test of Gaze Following, Neural Networks, 23(8-9), pp. 966–972, 2010.

[9] A. N. Meltzoff, P. K. Kuhl, J. Movellan, and T. J. Sejnowski, Foundations for a New Science of Learning, Science, 325(5938), pp. 284–288, 2009. [Online]. Available: http://www.sciencemag.org/cgi/doi/10.1126/science.1175626 (visited on 04/30/2018).

[10] D. H. Lee and A. K. Anderson, Reading What the Mind Thinks From How the Eye Sees, Psychological Science, 28(4), 2017.

[11] P. Ekman and W. V. Friesen, *UNMASKING THE FACE: A Guide to Recognizing Emotions from Facial Expressions*, 212 pp., Malor Books, 2003.

[12] G. Faigin, *The Artist's Complete Guide to Facial Expression*, 288 pp., New York, NY: Watson-Guptill, 1990.

[13] P. Desmet, K. Overbeeke, and S. Tax, Designing Products with Added Emotional Value: Development and Appllcation of an Approach for Research through Design, The Design Journal, 4(1), pp. 32–47, 2001.

[14] S. Song and S. Yamada, Expressing Emotions through Color, Sound, and Vibration with an Appearance-Constrained Social Robot, In: Proceedings of the 2017 ACM/IEEE International Conference on Human-Robot Interaction - HRI '17, pp. 2–11, ACM, 2017.

[15] H. Kobayashi and S. Kohshima, Unique morphology of the human eye and its adaptive meaning: comparative studies on external morphology of the primate eye, Journal of Human Evolution, 40(5), 2001.

[16] D. E. Knuth, *The Art of Computer Programming, Seminumerical algorithms*, 3rd ed. vol. 2, 767 pp., Addison-Wesley, 1998.