Investigation on Effects of Color, Sound, and Vibration on Human's Emotional Perception

Sichao Song
Department of Informatics
The Graduate University for Advanced Studies (Sokendai)
2-1-2 Hitotsubashi, Chiyoda, Tokyo, Japan
sichaos@nii.ac.jp

Seiji Yamada
National Institute of Informatics
The Graduate University for Advanced Studies (Sokendai)
2-1-2 Hitotsubashi, Chiyoda, Tokyo, Japan
seiji@nii.ac.jp

ABSTRACT
As robotics has advanced, research on conveying a robot's emotional state to a person has become a hot topic. Most current studies are focused on interaction modalities such as facial expressions and natural language. Although many of the results seem to be promising, they suffer from high cost and technical difficulties. In this paper, we turn our attention to three other interaction modalities: color, sound, and vibration. Such modalities have the advantage of being simple, low cost, and intuitive. We conducted a pilot study to evaluate the effects of the three modalities on a human's emotional perception towards our robot *Maru*. Our result indicates that humans tend to interpret a robot's emotion as negative (angry in particular) when vibration and sound are used, while they interpret the emotion as relaxed when only color modality is used. In addition, the participants showed preference towards the robot when using all three modalities.

ACM Classification Keywords
H.5.m. Information Interfaces and Presentation (e.g. HCI): User Interfaces - Theory and methods

Author Keywords
Color; Sound; Vibration; Emotional expression of a robot; Multi-modalities; Human-Agent Interaction (HAI); HRI; HCI.

INTRODUCTION
As robotics has advanced, research on conveying a robot's emotional states to a person has become a hot topic. As over 80% of human communication is encoded in facial expressions and body movements [5], most of the current studies are focused on interaction modalities, for instance, facial expressions, natural language, and body gestures. Although many of them have shown promising results, they suffer from high cost and technical difficulties.

HAI '16, October 04-07, 2016, Biopolis, Singapore
ACM 978-1-4503-4508-8/16/10.
http://dx.doi.org/10.1145/2974804.2980497

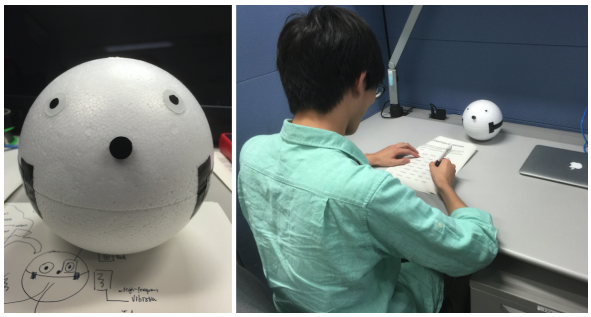

Figure 1. Maru and the experiment setting.

To make the interaction design simple, low cost, and intuitive, we turn our attention to three other modalities: *color*, *sound*, and *vibration*. Previous studies have shown their impact on a person's perception [2, 6, 7]. However, to the best of our knowledge, there is no work that comprehensively evaluated the effect of these three modalities in a scenario involving the emotional expression of a robot.

In this paper, we present our pilot study on this topic. We evaluate a human's perception towards a robot conveying its emotions through the three modalities. A ball-shaped robot named "Maru" was designed in order to conduct a user experiment. To be specific, we wanted to see how participants interpret Maru's emotions in three cases: one modality (color), two modalities (vibration and sound), and all three modalities.

METHODS AND DESIGN
We used the circumplex model of affect to map emotions onto a valence-arousal space. In particular, we focused on four emotions, *relaxed*, *happy*, *sad*, and *angry*, where each emotion can be mapped onto a different quadrant of the valence-arousal space. We first conducted a pre-design phase to decide a limited candidate cue pool for our user experiment. This is because each modality can be associated with many factors, resulting in a design space that is too large.

Pre-design Session
At the beginning stage of the study, we wanted to prepare a candidate cue pool with a total of 12 candidate cues (3 modalities $\times$ 4 emotions) in order to constrain our design space. Previous studies suggest that colors can be considered as having the attribute to evoke different emotions [3, 6]. Accordingly, we

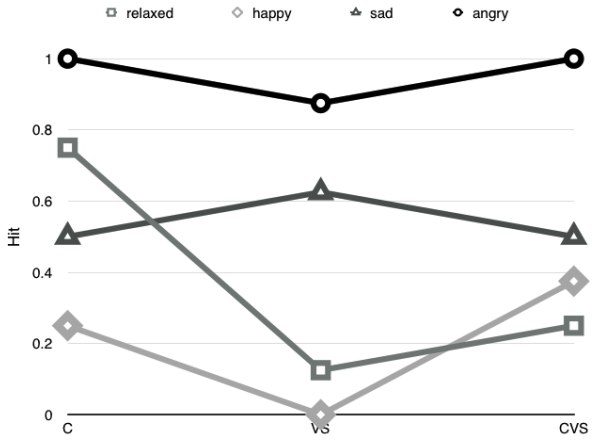

Figure 2. Modalities vs. Hit (C: color, V: vibration, S: sound)

decided to associate relaxed with white, happy with green, sad with blue, and angry with red. [2, 1, 7] indicate that both sound and vibration can be informative in discriminating between levels of valence (positive and negative) and levels of arousal. For instance, [1] claims that sounds with upward slopes were interpreted as "disagreement", and [2] shows that a decreasing ASE successfully conveyed "low confident" state to the users. Thus, we decided to associate a flat beep sound with a positive state, rising-pitch beep sound with a negative and high arousal state, and falling-pitch beep sound with a negative and low arousal state. We also designed four levels of vibration intensity, where a higher intensity indicates a higher level of arousal.

Designing the Robot Maru

We intentionally made Maru's embodiment and appearance as simple as possible while still having the attribute of anthropomorphism (see Figure. 1). The robot is made of two pieces of hollow semi-spherical Styrofoam. Four LEDs (white, green, blue, and red) were assembled behind each eye. In addition, a speaker is used to generate beep sound cues, and a vibration motor is attached to the inner body to produce vibration cues. An Arduino UNO board was programmed to control the robot.

EXPERIMENT

Eight Japanese (4 males and 4 females) ranging from 22 to 39 years old (M = 27.88, SD = 5.94) participated the study. The experiment was a 3 × 5 within-subject design with two independent variables: *combination of modalities* [one modality (color), two modalities (vibration, sound), three modalities (color, vibration, sound)] and *emotion* (relaxed, happy, sad, angry). We evaluated one dependent variable: *hit* [correctly recognized an emotion (1) and incorrectly recognized an emotion (0)]. In addition, we collected participants' preferences towards the three modalities via a post questionnaire using 7-point Likert scales. An example question is "do you think you recognize Maru's emotions better when using three modalities (color, vibration, sound) rather than the other two cases (one and two modalities)?"

RESULTS AND DISCUSSION

Figure 2 demonstrates our result. A two-way repeated-measure ANOVA on both factors for the dependent variable was conducted. From the result, no significant difference in the main effect of *combination of modalities* [$F(2,14) = 1.87$, n.s.] was found, indicating that *hit* across the four emotions does not change much with different combinations of modalities. However, *emotion* showed a significant effect [$F(3,21) = 10.79$, $p<0.001$]. A Tukey's HSD test showed that among the four emotions, angry ($M_{hit} = 0.96$) was recognized significantly better than relaxed ($M_{hit} = 0.38$, $p<0.001$), happy ($M_{hit} = 0.21$, $p<0.001$), and sad ($M_{hit} = 0.58$, $p<0.05$). In addition, sad was also recognized significantly better than happy ($p<0.05$). No other significant differences were found.

We also observed a significant difference in the *combination of modalities* × *emotion* interaction effect [$F(6,42) = 2.98$, $p<0.05$]. This indicates that emotional perception changes depending on the different combination of modalities. There is no single combination of modality that is effective for all kinds of emotions. Paired sample *t*-tests with Bonferroni correction were conducted in light of the significant interaction. We see that relaxed was recognized significantly better using only color modality compared with using two modalities [$t(7) = 2.65$, $p<0.05$] and three modalities [$t(7) = 3.42$, $p<0.05$]. However, we did not find significant differences regarding the other three emotions.

In addition, an analysis of the questionnaires indicated that the participants preferred when the robot used all three modalities rather than only one or two modalities. From the result, we propose our preliminary design guideline based on the conclusions from our result. We suggest using only color modality (white) to express relaxed. Negative emotions such as sad and angry, in order to be iconic, are strongly recommended to be expressed through vibration and sound to. Specifically, we suggest conveying angry using all three modalities while conveying sadness using two modalities without color.

FUTURE WORK

We will later conduct experiments on the three modalities with larger number of participants. Particularly, we will focus on the expression of happy and sad, and more combinations of modalities will be examined. Further, we are considering expanding the current system with biometric sensors such as ECG and EDA. In addition, we are especially interested in the concept of *agent migration* [4]. We will investigate how to shift the heavy amount of work on emotional communication from the robot side to a third-party device such as a wearable device through modalities such as color, vibration, and sound by applying the idea of agent migration.

ACKNOWLEDGEMENTS

This study was partially supported by JSPS KAKENHI "Cognitive Interaction Design" (No.26118005).

REFERENCES

1. Takanori Komatsu. 2005. Toward making humans empathize with artificial agents by means of subtle expressions. In *Affective Computing and Intelligent Interaction*. Springer, 458–465.

2. Takanori Komatsu, Seiji Yamada, Kazuki Kobayashi, Kotaro Funakoshi, and Mikio Nakano. 2010. Artificial subtle expressions: intuitive notification methodology of artifacts. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*. ACM, 1941–1944.
3. Niels A Nijdam. 2009. Mapping emotion to color. *)ˆ(Eds.):âĂŸBook Mapping emotion to colorâĂŹ(2009, edn.)* (2009), 2–9.
4. Kohei Ogawa and Tetsuo Ono. 2008. ITACO: Effects to interactions by relationships between humans and artifacts. In *Intelligent Virtual Agents*. Springer, 296–307.
5. Jocelyn Scheirer and R Picard. 2000. Affective objects. *MIT Media lab Technical Rep.* 524 (2000).
6. Marina V Sokolova and Antonio Fernández-Caballero. 2015. A review on the role of color and light in affective computing. *Applied Sciences* 5, 3 (2015), 275–293.
7. Shafiq ur Réhman and Li Liu. 2010. ifeeling: Vibrotactile rendering of human emotions on mobile phones. In *Mobile Multimedia Processing*. Springer, 1–20.