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What Kinds of Facial Self-Touches Strengthen Expressed Emotions?

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Figure 1. Collected facial self-touch gestures in our data collection

***Abstract*—As virtual spaces continue to attract more and more attention, the development of virtual agents is also gaining momentum. Agents capable of expressing emotions are being developed, and various methods exist through which they express such feelings. Although much research has focused on the implementation of human actions in agents, no research has yet implemented facial self-touch for agents used in emotional expressions, even though such transmission of human emotions is a critical tool for them. In this study, we developed a system that enriches agents' emotional expressions by implementing self-touches in virtual agents. From an evaluation of our system, we found that it enhances the emotions of virtual agents. The naturalness of their emotional expressions varied depending on the emotion.**

I. Introduction

Emotional expression is an essential factor for achieving natural and acceptable human-robot interactions [1, 2]. For example, robotics researchers have developed rich hardware that has adequate capabilities to express various kinds of human-like facial expressions [3-5]. Other researchers have also focused on emotional expression in interactions with people, such as speaking situations [6-9] and body movement [10-13]. These studies reported how designing emotional expressions contributes to human-robot interaction studies.

As a novel approach for enriching emotional expression by gestures, self-touch, which is the act of touching oneself in relationship to the expressions of emotion, is attracting attention. For example, a past study reported that a self-adaptor, which is a type of non-signaling gesture that includes self-touches, reflects emotional stability [14]. Other studies also investigated the effects of showing self-adaptors toward the perceived social skills of virtual agents [15, 16]. Other studies concentrated on the relationships between facial self-touch and emotions. A past study investigated the self-touch patterns toward people's own faces and identified the relationships between the patterns and perceived both cognitive and emotional load [17]. Other studies also discussed the relationships between facial self-touch and emotions [18, 19].

These previous studies suggest the effectiveness of facial self-touches to express emotions and provided rich knowledge on how to implement such behaviors, although they focused less on using touch behaviors for social robots. In the context of touching behavior to express emotion, robotics researchers have investigated the effects of various kinds of touching behaviors [20-22]. For instance, some studies investigated what kinds of touching behaviors from robots to interacting people or objects match expressed emotions [23-28].

However, these past studies focused less on facial self-touches by the robot of itself, although they enabled social robots to touch others to display emotions. Furthermore, as verified in past studies, emotional expression using touch behaviors is impossible without such touching targets as others to interact with or objects. When an agent is placed in a rather stark environment, as in a monologue or a stand-alone presentation, using touch behaviors for emotional expression is difficult based on the current knowledge from past studies. If we can clarify what kind of emotional expressions a robot can make by touching itself, the findings will provide useful insights into the design of robot behaviors.

Based on these considerations, as a first step, we develop an emotional expression model based on facial self-touches using virtual agents, similar to past studies [15, 16]. We gathered basic facial self-touch behaviors from a relatively small-scale preliminary data collection (Fig. 1) and conducted another data collection through a web survey to investigate what kinds of facial self-touch behavior match emotional expressions. Based on the gathered data, we also developed a mechanism to derive appropriate facial self-touch behaviors reflect expressed emotions.

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II. DATA COLLECTION OF VARIETY OF FACIAL SELF-TOUCHES

A. Target facial self-touch

Following a past study [29], a facial self-touch is categorized into two types: active and spontaneous. The former is an intentional face touch, such as responding to a pain stimulus, itching, or such social cues as tapping one's forehead. The latter is a completely unconscious initiation and execution of a face touch. A past study described the differences of the neurophysiological characteristics of these two types [30].

Several past studies conducted data collections of spontaneous facial self-touches and implemented them as the self-adaptor behaviors of virtual agents [18, 19]. However, since they focused on spontaneous and unintentional facial self-touches, it remains unknown what kinds of facial self-touches match the expressed emotions. In addition, to collect facial self-touch data associated with emotional expressions, it is difficult in principle to collect spontaneous facial self-touch data, because the subjects must intentionally express their emotions.

Based on these considerations, we gathered active facial self-touches during emotional expressions because we believe that merely gathering active self-touch data is useful for strengthening emotional expressions. The observers themselves of facial self-touches struggle to recognize whether a self-touch is active or spontaneous. Therefore, rigorously measuring the effect on facial self-touches toward emotion expression by the presence or absence of intention is also difficult. We instead asked the participants to imagine realistic situations and reproduce the facial self-touches that might occur in such situations, as is done in data collection with human participants.

B. Data collection procedures

Our preliminary data collection gathered a variety of facial self-touches with different emotional expressions. We modified instructions from a previous work [31] to gather facial self-touches when people expressed Ekman's six basic emotions [32]. The details of the instructions are described below:

Happy: if someone gave you a present that you had always wanted, you would be glad. You would be pleased and happy.

Sad: if your best friend moved away to another town, you would be unhappy. You would be sad that they were leaving.

Afraid: if you did not like being alone in the dark and one night you were in the house on your own and all the lights went out, you would be frightened. You would feel afraid.

Surprised: if you opened a box thinking that there was nothing inside and a kitten jumped out, you would be surprised. You would not have expected anything to be inside the box.

Angry: if you've done something that someone told you not to do, that person would be displeased with you. They would be angry.

Disgust: if you've encountered a scene with a dense population of insects, you feel disgust, uncomfortable.

Six participants joined this data collection. We first describe its purpose and explain the modified instructions to imagine and reproduce situations with facial self-touches. Then we video-recorded their performances that expressed various emotions and analyzed how they touched their face while expressing each emotion. We gathered 19 unique facial self-touches (Fig. 1) and used them to model the relationships between emotional expressions and appropriate facial self-touches through another data collection described in the next section.

III. DATA COLLECTION FOR MODELING FACIAL SELF-TOUCHES

A. Data collection and modeling

To model appropriate facial self-touches for emotional expressions, we employed Russell's diagram (Fig. 2) [33] to gather data to represent the relationships between Ekman's six emotions and our gathered facial self-touch data. We conducted a web-based survey for this purpose.

For this survey, 201 participants (100 men and 101 women) joined this data collection. They observed movies where a virtual agent performed facial self-touches gathered from our preliminary data collection and clicked on the position in Russell's diagram (Fig. 2, where resolution of each axis is 100 pixels) to represent the emotions expressed by the agent. Thus, the participants evaluated each facial self-touch from both valence and arousal perspectives. They also answered dummy questions after each evaluation to determine how closely they were observing each video. In the end, we eliminated the data of 50 people who incorrectly responded.

Figure. 3 shows examples of the data gathered toward a specific facial self-touch. We eliminated outliers using the local outlier factor (LOF) method and performed a kernel density estimation to derive the probability distribution of each facial self-touch (right). This distribution indicates the frequencies at which each facial self-touch is appropriate when the emotion is expressed on the arousal and valence axes. Finally, we integrated and normalized 19 probability distributions to enable a system that selects appropriate facial self-touches depending on the arousal and valence values.

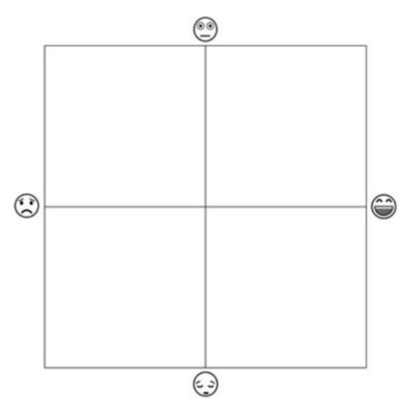

Figure 2. Russell's diagram used in our data collection

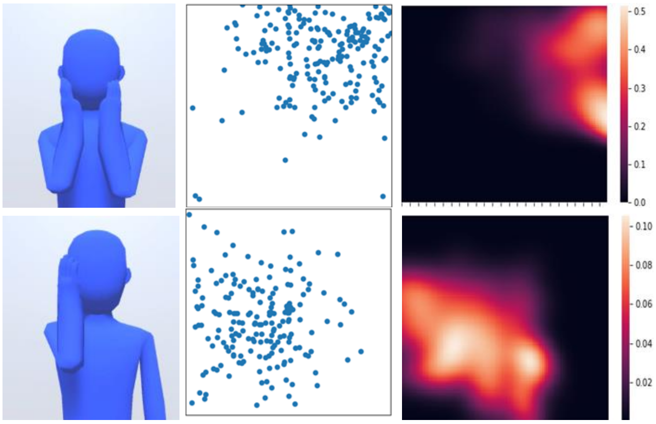

Figure 3. Example facial self-touch data, clicked positions, and probability distributions (normalized to account for other facial self-touch data)

Figure 4. Facial expressions (angry, fear, disgust, happy, surprised, sad) by virtual agent (man)

Figure 5. Virtual agent (woman) touching her face based on probability distribution

B. *Implementation*

Based on the integrated probability distributions, we developed a system for selecting appropriate facial self-touches while virtual agents expressed emotions. Our system consists of Russell's diagram-based GUI and virtual agents. The GUI has three functions that 1) set Ekman's six emotions in virtual agents, 2) change the appearances of the virtual agents into either those of a man or a woman, and 3) change the emotional expression methods: *none* (only in facial expressions, as shown in Fig. 4), *random* (randomly selects facial self-touches with facial expressions), and *proposed* (using the probability distribution to select facial self-touches with facial expressions, as shown in Fig. 5).

IV. EXPERIMENT

Our experiment evaluated whether our system of facial self-touches based on a derived probability distribution is appropriate to strengthen emotional expressions.

A. *Hypothesis and prediction*

Past studies investigated the relationships between emotions and facial self-touches [17-19]. Some implemented functions to express internal states [18, 19] or emotions [23-28] through self-touches, although they focused less on relationships between appropriate facial self-touches to strengthen the expressed emotions.

To identify appropriate facial self-touches, we conducted data collections to investigate basic facial self-touch patterns and the relationships among facial self-touches, arousal, and valence. Based on the analysis of the gathered data, we derived a probability distribution to select appropriate facial self-touches for the given arousal and valence values. If the modeling is appropriate, the selected facial self-touch will be perceived as stronger and more natural than randomly selected facial self-touch. Based on this hypothesis, we made the following two predictions:

Prediction 1: If agents use facial self-touches based on our *proposed* model when they express emotions by facial expressions, their facial self-touches will be perceived as stronger than the agent who uses randomly selected facial self-touches.

Prediction 2: If agents use facial self-touches based on the *proposed* model when they express emotions by facial expressions, such actions will be perceived as more natural than an agent that uses randomly selected facial self-touches.

B. *Participants*

We recruited from a Japanese survey company 183 people (94 men and 89 women) whose average age was 41.7.

C. *Conditions and visual stimuli*

The experiment had a mixed-participant design. Each participant experienced the four conditions under two factors with a within-participant design: the condition factor: (*proposed*, the agent uses the *proposed* method to select a facial self-touch, and *alternative*, the agent used the *random* method that arbitrarily selected facial self-touches) and the agent-gender factor (*man* or *women*). In both conditions, the agents used facial self-touches five times, selected each time according to the assigned condition. Each facial self-touch was chosen based on the probability distribution or randomly based on the assigned condition. We also employed a participant-gender factor as a between-participant design.

D. *Measurements*

To compare and investigate the perceived strength and the naturalness of emotions expressed by the virtual agents, the participants filled two aspects in the questionnaires: perceived strength and perceived naturalness. We used a response format on an 11-point scale for these questionnaires, i.e., describing the options ranging from most negative (not strong/not natural) to most positive (strong/natural). As a basis of comparison, we explained that the case of only facial expressions deserved to be median values.

E. Procedures

All the procedures were approved by the Advanced Telecommunication Research Review Boards (501-3). A consent form was displayed on the beginning of the webpage. Only participants who agreed with it were accepted by our survey. They read explanations of the experiment and how to evaluate each video. As a baseline, they first observed the agents' facial expressions. Then the participants watched videos (*proposed* and *alternative*) for one of the six emotions with either man or woman agent and answered questionnaires. After observing both videos, they also watched two videos for an agent of the opposite gender. The participants repeated this process until they observed all the emotions' videos. In the end, the participants answered a dummy question. The orders of the conditions, the agent, and the emotions were counterbalanced.

V. RESULT

A. Angry

The results of the mixed design three-factor ANOVA for the perceived strength of angry (Fig. 6-a, Table 1) showed significant differences for the condition factor (p<0.001), for the agent's gender (p<0.001), and for the first order interaction between the condition factor and the agent's gender (p=0.003). The results of the post hoc tests showed significant differences between the condition factor when the agent's gender was *man* (p<0.001), between the condition factor when the agent's gender was *woman* (p=0.002), and between the agent's gender in the *alternative* condition (p<0.001).

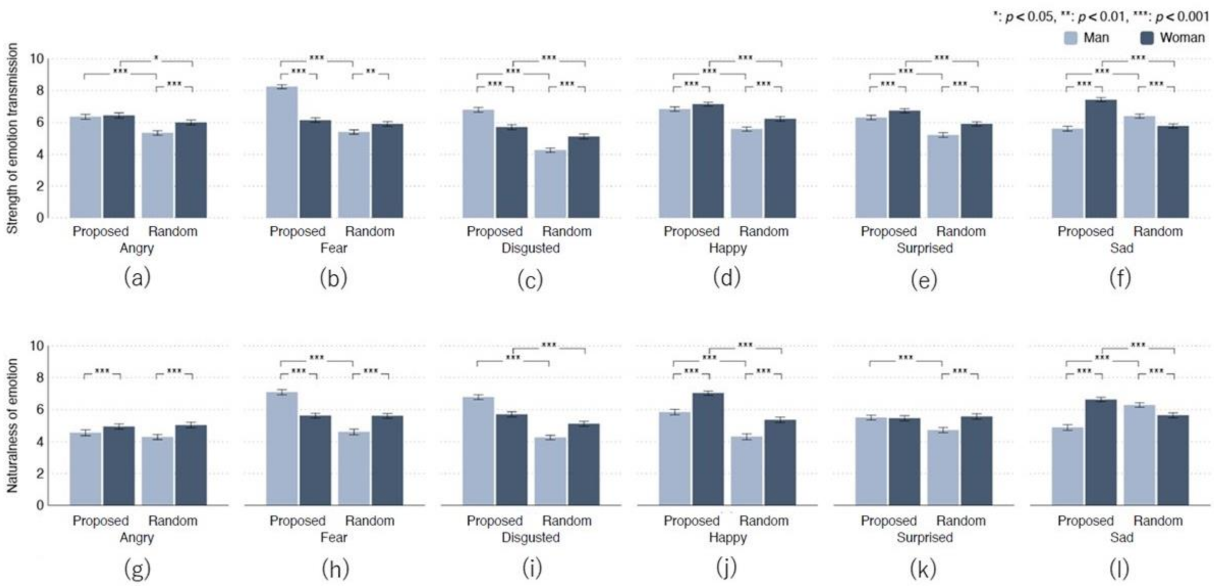

Figure 6. Questionnaire data about strength (a-f) and naturalness (g-l) (average and S.E.)

TABLE I. Statistic results of strength and naturalness (Bold indicates that p-value is less than 0.05)

		P					
	Source	Angry	Fear	Disgust	Happy	Surprised	Sad
Strength	Condition (C)	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**
	Agent (A)	**<0.001**	**<0.001**	0.395	**<0.001**	**<0.001**	**<0.001**
	Human (H)	0.771	0.691	0.647	0.299	0.972	0.172
	C*A	**0.003**	**<0.001**	**<0.001**	0.070	0.143	**<0.001**
	C*H	0.603	0.673	0.987	**0.036**	0.595	0.153
	A*H	0.726	0.469	0.419	0.817	0.381	0.836
	C*A*H	0.813	0.930	0.604	0.645	0.463	0.587
Naturalness	Condition (C)	0.372	**<0.001**	**<0.001**	**<0.001**	**0.010**	0.097
	Agent (A)	**<0.001**	**0.035**	0.433	**<0.001**	**0.002**	**<0.001**
	Human (H)	0.521	0.849	0.804	0.672	0.775	0.850
	C*A	0.066	**<0.001**	0.518	0.531	**<0.001**	**<0.001**
	C*H	0.291	0.966	0.853	0.055	0.809	0.693
	A*H	0.425	0.242	**0.042**	**<0.001**	0.296	0.090
	C*A*H	0.982	0.221	0.604	0.625	0.952	0.386

The results of a mixed design three-factor ANOVA for the perceived naturalness of angry (Fig. 6-g, Table 1) showed a significant difference for the agent's gender (p<0.001).

B. Fear

The results of the mixed design three-factor ANOVA for the perceived strength of fear (Fig. 6-b, Table 1) showed significant differences for the condition factor (p<0.001), for the agent's gender (p<0.001), and for the first order interaction between the condition factor and the agent's gender (p<0.001). The results of the post hoc tests showed significant differences between the conditions when the agent's gender was *man* (p<0.001), between the agent's gender in the *proposed* condition (p<0.001), and between the agent's gender in the *alternative* condition (p<0.001).

The results of a mixed design three-factor ANOVA for the perceived naturalness of fear (Fig. 6-h, Table 1) showed significant differences for the condition factor (p<0.001), for the agent's gender (p=0.035), and for the first order interaction between the condition factor and agent's gender (p<0.001). The results of the post hoc tests showed significant differences between the conditions when the agent's gender was *man* (p=0.043), between the agent's gender in the *proposed* condition (p=0.027), and between the agent's gender in the *alternative* condition (p<0.001).

C. Disgust

The results of a mixed design three-factor ANOVA for the perceived strength of disgust (Fig. 6-c, Table 1) showed significant differences for the condition factor (p<0.001) and for the first order interaction between the condition factor and the agent's gender (p<0.001). The results of the post hoc tests showed significant differences between the condition factor when the agent's gender was *man* (p<0.001), between the condition factor when the agent's gender was *woman* (p<0.001), between the condition factor in the *proposed* condition (p<0.001), and between the agent's gender in the *alternative* condition (p<0.001).

The results of a mixed design three-factor ANOVA for the perceived naturalness of disgust (Fig. 6-i, Table 1) showed significant differences for the condition factor (p<0.001) and for the first order interaction between the genders of the participants and the agents (p=0.042). The results of the post hoc tests showed significant differences between the agent's gender when the participant's gender was *man* (p=0.043).

D. Happy

The results of a mixed design three-factor ANOVA for the perceived strength of happy (Fig. 6-d, Table 1) showed significant differences for the condition factor (p<0.001), for the agent's gender (p<.001), and for the first order interaction between the participant's gender and the condition factor (p=0.036). The results of the post hoc tests showed a significant difference between the conditions when the participant's gender was *man* (p<0.001) and between the condition factor when the participant's gender was *woman* (p<0.001).

The results of a mixed design three-factor ANOVA for the perceived naturalness of happy (Fig. 6-j, Table 1) showed significant differences for the condition factor (p<0.001), for the agent's gender (p<0.001), and for the first order interaction between the participant's gender and the agent's gender (p<0.001). The results of the post hoc tests showed significant differences between the participant's gender when the agent's gender was *woman* (p=0.030), between the agent's gender when the participant's gender was *man* (p<0.001), and between the agent's gender when the participant's gender *woman* (p<0.001).

E. Surprised

The results of a mixed design three-factor ANOVA for the perceived strength of surprised (Fig. 6-e, Table 1) showed significant differences for the condition factor (p<0.001) and the agent's gender (p<0.001).

A mixed design three-factor ANOVA for the perceived naturalness of surprised (Fig. 6-k, Table 1) showed significant differences for the condition factor (p=0.010), for the agent's gender (p=0.002), and for the first order interaction between the condition factor and the agent's gender (p<0.001). The results of the post hoc tests showed significant differences between the condition factor when the agent's gender was *man* (p<0.001) and between the agent's gender in the *alternative* condition (p<0.001).

F. Sad

The results of a mixed design three-factor ANOVA for the perceived strength of sad (Fig. 6-f, Table 1) showed significant differences for the condition factor (p<0.001), for the agent's gender (p<0.001), and for the first order interaction between the condition factor and the agent's gender (p<0.001). The results of the post hoc tests showed significant differences between the condition factor when the agent's gender was *man* (p<0.001), between the conditions when the agent's gender was *woman* (p<0.001), between the agent's gender in the *proposed* condition (p<0.001), and between agent's gender in the *alternative* condition (p<0.001).

The results of a mixed design three-factor ANOVA for the perceived naturalness of sad (Fig. 6-l, Table 1) showed a significant difference for the agent's gender (p<0.001) and for the first order interaction between the condition factor and the agent's gender (p<0.001). The results of the post hoc tests showed significant differences between the conditions when the agent's gender was *man* (p<0.001), between the conditions when the agent's gender was *woman* (p<0.001), between the agent's gender in the *proposed* condition (p<0.001), and between the agent's gender in the *alternative* condition (p<0.001).

G. Summary

The results showed that the developed system adequately strengthened the expressed emotions compared to random facial self-touches, except for sad emotions by the *man* agent. The results also showed that the developed system enabled more natural facial self-touches compared to the *alternative* condition for fear, disgust, happy, and surprised. The facial self-touches for anger might decrease naturalness because the results are lower than the median value, although a facial self-touch effectively strengthened anger.

VI. Discussion

A. Implication

This study has several implications. First, it modeled facial self-touches to strengthen how emotions are expressed by virtual agents. This knowledge can be extended not only to such virtual agents but also to social robots (the next subsection describes an example of implementations of this system for a social robot). One interesting research topic is considering cultural differences. Since this study only gathered basic facial self-touches from Japanese participants, additional data collection from different countries and modeled probabilistic distributions is required.

Another implication is the gender combination effects. We initially assumed that the genders of both the participants and the agents would be influenced toward the effects of facial self-touches in expressing emotions. However, only the agent's genders influenced the perceived strength and the majority of the perceived naturalness. Based on the considerations of such gender effects, one future work will change the facial self-touches due to the agents' gender to effectively strengthen the expressed emotions. In the data collection, we integrated the gathered data about the relationships between facial self-touches and valence/arousal mapping from men and women, although calculating probabilistic distributions considering observers' genders is another interesting future work.

B. Implementation for social robots

Based on our analysis, we implemented a facial self-touch behavior selection system on a desktop-sized (28 cm high) social robot called Sota. Since it has no facial expression function, we used its eyes' LEDs to express emotions by changing their colors, as was done in a past study [34] (Fig. 7). Moreover, since the DOFs of its arm are different from those of the virtual agents, we modified the facial self-touch behaviors based on the robot's capability.

Figure. 8 shows example facial self-touch behaviors of the robot when the developed system sent appropriate facial self-touches to it. We tested the developed system and confirmed that the robot autonomously chose facial self-touches based on the coordinates selected on the two axes of arousal and valance.

C. Limitation

This study has several limitations. First, we gathered the basic facial self-touches from a relatively tiny number of Japanese participants. Therefore, gathering more self-touch data and from different countries is essential for more natural and generalized facial self-touches. Moreover, First, we only implemented the model to a specific robot, i.e., Sota, using different robots, such as human-like robots [3, 35], would need different modeling approach and produce different impressions. Although we implemented the facial self-touch behavior selection system for a social robot, we did not evaluate it; additional experiments are important to evaluate its effectiveness.

Figure 7. Sota's emotional expressions with LED color change only (angry, fear, disgust, happy, surprised, sad)

Figure 8. Sota's emotional expressions with LED color change and facial self-touch (angry, fear, disgust, happy, surprised, sad)

VII. Conclusion

This study developed a facial self-touch selection system and evaluated by using virtual agents. We first conducted a preliminary data collection to gather the basic facial self-touches and conducted an additional data collection to investigate the relationships between facial self-touches and emotions using Russell's diagram, which consists of arousal and valence axes. From the gathered data, we developed a facial self-touch selection system based on the probabilistic distributions of facial self-touches. We experimentally investigated the effectiveness of our proposed system, and its results showed that our proposed system strengthened the expressed emotions more than the random facial self-touches, except for sad emotions by *man* agents. The results also showed that the developed system enabled more natural facial self-touches than the *alternative* condition for four emotions: fear, disgusted, happy, and surprised.

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