Emotional or Social?: How to Enhance Human-Robot Social Bonding

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ABSTRACT
The behavior of a social robot is designed based on either its emotional state or social situation. In this research, we defined these expressions as the affective and social expressions, and proposed a new emotional expression method to integrate these two expressions. It is known that a human has involuntary facial muscles around the eyes, and voluntary facial muscles around the mouth. Thus, it is considered that facial muscles around the eyes express the affective expressions, while facial muscles around the mouth express the social expressions. In an experiment involving a human-robot conversation, using the proposed method, the results showed a sense of human likeness and sociality. Furthermore, the intimacy evaluation results showed that the social expressions work effectively when the intimacy does not require high social bonding such as the desire for friendship. However, the affective expressions are necessary for evaluating intimacy that requires higher social bonding, such as wanting to live with someone.

Author Keywords
Robot; Emotion; Facial expression; Duchenne smile; Human likeness; Sociality; Intimacy;

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H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous

INTRODUCTION
In recent years, robots have become popular in our daily lives because of their work with humans. They have to be recognized as a social entity. However, the problem is that a robot is rarely treated like a human. For example, in the previous experiments, non-social behaviors were observed towards an autonomous robot, which do not occur when people meet for the first time [14]. Moreover, the participants responded to the greetings of a teleoperated robot, but ignored the greetings of an autonomous robot [18]. From these results, it appears that people generally do not tend to treat robots as a social entity. If people can recognize robots as social entities similar to humans, there is a possibility that robots can be utilized as conversational partners. For instance, to assist with suppressing loneliness for the elderly, or attending to students during a lecture; therefore, robots can further promote our daily lives.

We considered that the emotional expressions of robots could be one of the factors that could make people recognize robots as social entities. In human-human communication, various communication channels are used for transferring information; a visual channel including facial expressions play an important role [17]. Facial expressions convey emotional states and intentions [4,5], and so, many robots that exhibit various facial expressions are proposed. Therefore, robots that exhibit various facial expressions are proposed. Such robots will express facial expressions corresponding to the robot's emotional state, for the human to understand easily [1,6,11]. However, it is appropriate for shopkeeper robots, which have to behave sociably for customers, to express sociality according to the situation, regardless of the robot's emotional state [8,20].

Emotional expressions of robots are designed based on either the emotional state or social situation of the robot. However, in human-human communication, the emotional expressions are based on both the emotional state and social situation. For example, when we are annoyed, in some cases, we express our unpleasant feelings blatantly. However, in some cases, we present a fake smile, depending on the social situation. A false smile is called a Non-Duchenne smile (hereinafter referred to as NDS). A true smile based on a pleasant feeling is called a Duchenne smile (hereinafter referred to as DS). NDS and DS can be distinguished by the presence or absence of involuntary contraction of facial muscles around the eyes [5].

In this research, we develop a robot that reproduces emotional expressions similar to that of a human. Using the proposed method, we combine the voluntary expressions based on sociality and the involuntary expressions based on emotion. We conducted an experiment to evaluate the impression of the robot, and investigated the influence of

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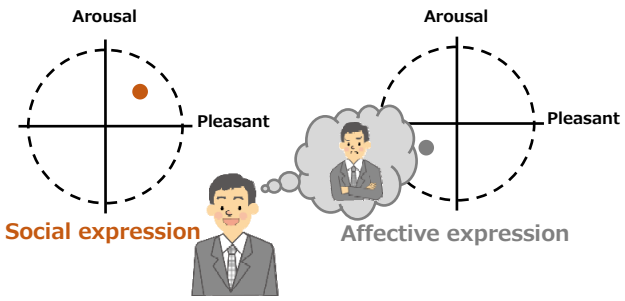

Figure 1. Our Proposing Emotion Expression Model

different emotional expressions of the robot on its social relationship with the human.

RERATED RESEARCH

There are many robots that exhibit various facial expressions[1][6][11] . An effective method for human-robot communication is for a robot to express facial expressions that are based on its emotions. Take for instance, a robot that can express facial expressions corresponding to a stimulus such as human stroking or striking [1]. In the research on robot emotional expression method, symbolic expressions and complex emotion expression mechanisms are used to express the internal state of the robot in an easy-to-understand manner [6,11]. The robot changes its facial expressions corresponding to the emotional states that are assigned to each facial expression by an outside stimulus. This method does not take into consideration the sociality of changing facial expressions depending on the opponent or situation. It emphasizes on the transmission of the internal state (emotion) of the robot to a human. Although this method may be appropriate for an animal-type robot such as a pet robot, for humanoids, it may result in poor sociality.

Humans do not always express their emotions directly; they use expressions that depend on the social situation and their position. It is known that an intentional expression of a smile makes a human be considered social and intelligent [16]. Such a sense of sociality lends intimate impressions when people meet for the first time [3]. Therefore, robots working in socially fast-paced environment, such as that of a receptionist, have been designed for social behaviors that depend on the situation instead of its emotions. For example, there are receptionist robots at an exhibition [8] and salesperson robots for a department store [20]. Such robots may have poor change of facial expressions due to excessive expression of the social smile at all times. Therefore, such a robot struggles to approach human-like impressions.

In this way, current robots interact with people according to either their emotional states or social situation. We proposed a method that designs an NDS-type robot that displays human-like expressions, based on its emotional state and social situation. In this research, we designed ambiguous facial expressions for a humanoid robot, such that the mouth is smiling but the eyes are not moving correspondingly.

EMOTION EXPRESSION MODEL AND FACIAL EXPRESSION OF ROBOT

Affective/social expression of robot

In this research, we focus on facial expression because it is one of the most obvious ways to convey emotion and sociality. Of course, they are other conceivable cues such as gesture and utterance, but unlike facial expressions, they lack the simultaneous expression of both emotion and sociality. As a result, NDS is convenient for testing our proposed method. We define facial expressions based on emotions as the affective expression, and sociality based on the social expression. As shown in Figure 1, we mapped motor commands corresponding to the movement of facial muscles to a two-dimensional plane of pleasantness/unpleasantness arousal/sleepiness with reference to Russell's Circumplex Model of Affect [10]. In this study, we call it the "emotion expression model".

Voluntary/Involuntary facial muscle of human

In many researches on the relationship between emotion and expression [2,4,5,19,21], it is revealed that the zygomaticus major muscle is activated by positive emotion and the corrugator supercilii muscle is activated by negative emotion [19]. We also know that facial expressions of pleasure are expressed by the contraction of the orbicularis oculi, zygomaticus major, and levator anguli oris muscles. Unpleasant facial expressions such as anger and sorrow are expressed by the contraction of the corrugator supercilii muscle [21]. To summarize, positive emotion activates the lower part of the face, and negative emotion activates the upper part of the face.

The research on deliberate control of facial expressions suggests that when a human tries to control facial expressions, they are more conscious toward controlling the mouth and lips than the eyes, eyelids, eyebrows, and forehead. In addition, it is generally said that camouflage of the facial expressions occurs in the lower part of the face, and it is rare that the eyebrows and forehead are used [5]. Therefore, in this research, we define the zygomaticus major as a voluntary facial muscle, and corrugator supercilii and orbicularis oculi as involuntary facial muscles. The research reproduced the actions of these muscles on the robot's face.

Implementation on robot

To implement the emotion expression model (Figure 1) on the robot, each axis on the face of the robot was associated with a human facial muscle. The NDS, in Figure 3, is the facial expression in a situation where the emotion of the robot is unpleasant, but it is required to smile sociably; that is, the affective expression is unpleasant, but the social expression is pleasant. We can confirm that although the mouth expresses a smile as a voluntary emotional expression, there are wrinkles around the eyebrows, that appear as an involuntary emotional expression.

HYPOTHESES

A smile is one of the facial expressions often seen in a social situation. It is said that a human tries to influence others by controlling facial expressions; hence, the smile plays an important role [5]. Based on this fact, in this research, we assumed a situation where the robot has to express a smile as a social expression. First, we examined what kind of impression is given by the affective and social expressions. We considered that the affective expression corresponds to an expression, such as a smile, to depict praise, and an angry expression corresponds to bad language. This gives the robot a sense of human likeness because they express the appropriate reactions. On the premise that emotions and facial expressions are consistent, most robots that can express various facial expressions display such emotional expressions [1,6,11]. From this, we considered that an emotional expression corresponding with the situation contributes toward a sense of human likeness; thus, hypothesis 1 is formulated.

Hypothesis 1: The unpleasant expression of the eyes and mouth corresponding to an unpleasant situation contributes toward a sense of human likeness.

Even if the reaction is to praise or not, it is reasonable to express a smile in situations where it is required to behave socially; for example, a dialogue with a person on the first meeting or customer service. It is desirable for a shopkeeper robot to express such a social expression [8,20]. As previously mentioned, a human camouflages facial expressions by controlling the mouth because it is difficult for a human to control the expression of the eyes. The eye-related emotions appear involuntary. From this fact, we considered that, regardless of the pleasantness/unpleasantness of the expression of the eyes, the facial expression of mouth that does not correspond to the situation shows a sense of sociality; thus, hypothesis 2.

Hypothesis 2: Regardless of the pleasantness /unpleasantness of the expression of the eyes, the facial expression of the mouth that does not correspond with the unpleasant situation contributes toward a sense of sociality.

The previous research shows that a smile plays a major role in communication between people [16]. It also evokes closeness in situations such as the first meeting [3]. From this fact, we considered that a smile in the situation of a first meeting contributes toward an intimate impression to a human; hence hypothesis 3.

Hypothesis 3: In the situation of the first meeting, the pleasant expressions of the eyes and mouth contribute to an impression of intimacy.

EXPERIMENT

Task

In order to verify the hypotheses in the previous chapter, we set up a scenario where two people talked to the robot. Of the two, one is the participant and the other is the experimenter. Hereinafter, we refer the experimenter as the interlocutor. In order to assume a social situation, we explained to the participant that this was the first meeting. After introducing the robot to the participant and the interlocutor, the robot asked three questions about the impression of its appearance: “What do you think about my hairstyle?”, “What do you think about my makeup?”, and “What do you think about my clothes?” The interlocutor responds first, followed by the participant last. In order to illustrate to the participant how to respond to the robot’s questions, the interlocutor answers first. Detailed procedures are described in “Procedure” section.

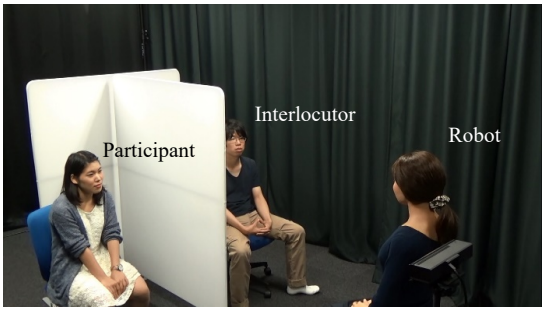

Figure 2. Experimental Environment

The situation was unpleasant for the robot because the participant gave negative responses such as, “your clothes do not suit you.” On the other hand, when the interlocutor provided positive responses, the robot expressed facial expressions that were affective and based on emotion and social expressions corresponding to sociality.

Experimental environment

Figure 2 shows the experiment environment. The person on the robot’s left is the participant and the person on the other side is the interlocutor. In order to let the participant pay attention to the robot rather than to the interlocutor, a partition was set up between them so that they cannot see each other.

Experimental condition

Based on the hypotheses, the difference between the three conditions is the facial expression of the robot when the participants state a negative opinion. When designing experimental conditions depending on the presence or absence of the affective/social expression, there are four types of expressions, as shown in Figure 3. However, because it is clear that the neutral condition, which constantly expresses the same facial expression without expressing emotion is unnatural and that is clearly disadvantageous compared with other conditions, we only compared the other three conditions.

NDS (Non-Duchenne Smile) condition: Based on the affective expression and the social expression, the robot expresses the NDS; the eyes express unpleasant emotions and the mouth expresses pleasant emotions.

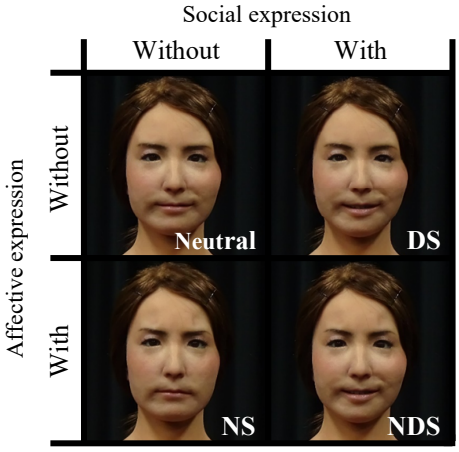

Figure 3. Facial Expressions of Our Robot

DS (Duchenne Smile) condition: The robot expresses pleasant expression (DS) of the eyes and the mouth based on the social expression rather than the affective expression. DS is originally defined as a true smile based on the robot's pleasant feelings; however, recent research shows that it is possible to express DS intentionally, irrespective of emotion [13], though individual differences in the ability of the expression exist [7]. The facial expressions of shopkeeper robots [8,20], which always express a smile, correspond to this condition.

NS (Non-Smile) condition: The robot expresses unpleasant expression at the eyes and the mouth based on the affective expression rather than the social expression. The facial expressions of robots of previous researches [1,6,11] display expressions based on emotion, and they correspond to this condition.

Hypothesis 1 predicts that NS and NDS give a higher sense of human likeness than DS. Hypotheses 2 and 3 predict that NDS and DS give a more social, intimate impression than NS.

When the robot introduces itself or asks questions, it expresses facial expressions of the neutral condition shown in Figure 3, while for the positive opinion of the experimenter, it expresses the same smile as DS in all conditions.

Participant

The participants were 48 undergraduates of our university, none of which were laboratory members. The experiment was carried out between participants' design; thus 16 (female: 8, Male: 8) participants were assigned for the NS condition, 16 (female: 8, Male: 8) participants were assigned for the NDS condition, and 16 (female: 8, Male: 8) participants were assigned for the DS condition.

Procedure

The experiment was conducted by the participant and three experimenters: the interlocutor, the experimenter who manages the experimental instruments, and the operator who operates the utterances such as the head orientation and facial expressions of the robot. The interlocutor sat in front of the robot, and the operator operated the robot from a position invisible to the participant, so that the participant would not know that the robot is being teleoperated. We explained the following to the participant, presenting the picture of the robot before meeting with the robot in order to ease their communication. Therefore, the robot was placed at the same social level as the human. In the experiment, we named the robot "Minami" to avoid to calling it "robot".

- Her name is Minami.
- Minami wants to be your friend.

The following was the explanation about the task.

- There is another interlocutor in this room, and you have to exchange one or two dialogues with Minami.
- There is a partition between the interlocutors so that you cannot see each other.
- You and another interlocutor are meeting Minami for the first time
- Minami will ask you some questions about your impression of her.
- For those questions, you state negative opinions only. For example, "your clothes do not suit you."

After the explanation, the participant sat so that they could not see the interlocutor, and then, the robot utters, controlled by the operator. In order to control changes in the facial expression initially presented to the participant between the conditions and to exemplify the answer for the robot, the interlocutor answered the question for the robot. After that, this was repeated three times in the order of the interlocutor /participant. At the beginning of the three questions, the robot asked the question, looking attentively with the facial expressions shown in Figure 3. Then, the robot turned to the interlocutor and asked for a reply as "How about you?" After answering the interlocutor, it expressed DS in Figure 3. Then, The robot asked the participant in the same manner as it asked the interlocutor and after the response by the participant, different expressions were expressed depending on the conditions. All the words of the robot were reproduced by synthesized speech. After approximately 120 s of dialogue, the participant left with the experimenter's guide and completed the questionnaire, which is described in the next section, in another room.

Questionnaires

After the dialogue with the robot, the participant answered the following items with the nine levels of the Likert scale and freely described the reasons for their answers.

Recognition of the robot's facial expression and degree of pleasantness/unpleasantness

To verify the hypotheses, we conducted a questionnaire for the participants to describe freely how they recognized the

	1st	2nd
Speak to her	**.990**	.118
Be friends with her	**.541**	.126
Listen to her	**.372**	.160
Low social bonding items		
Invite her to my home	.169	**.498**
Live with her	.054	**.996**
High social bonding items		
Exchange contacts with her	.353	.474

(Excluded because the loading amounts of the 1st and 2nd factors are close)

Figure 4. Factor Analysis of the Intimacy Items

expression of the robot, in order to confirm the validity of the experiment.

- What was the expression of Minami when another person was giving an opinion to Minami?
- (About the previous question) Why did you think Minami expressed such a facial expression?
- When you were giving an opinion to Minami, what kind of a facial expression did Minami express?
- (About the previous question) Why did you think Minami expressed such a facial expression?

Furthermore, we confirmed the degree of the pleasantness/unpleasantness of the robot that the participant felt from the facial expressions of the robot and the degree that the participant would express if they were in the place of the robot. It is said that when a human guesses the mental state of others, they infer the mental state as if they were in the same mental state [9]. From this fact, we considered that the difference between the degree of pleasantness/ unpleasantness that the participant felt from the facial expression of the robot and the degree that they would express if the participant was in the place of the robot could be evidence that the participant noticed the deceptive facial expression. We set the following items with nine levels of the Likert scale.

- When you gave a negative opinion, how large do you think was the degree of pleasantness / unpleasantness of Minami?
- If you were in Minami's place, how would you relate to the degree of pleasantness / unpleasantness?

Evaluation of human likeness

In order to verify hypothesis 1, we set the following item to evaluate the human likeness of the facial expression of the robot.

- Do you think the facial expression of Minami was appropriate as that of a human?

Evaluation of sociality

In order to verify hypothesis 2, we set the following item to evaluate the appropriateness of the facial expressions for the participant of the robot, in situations such as first meetings, where sociality is required.

- Do you think that the facial expression of Minami was generally appropriate for a person meeting another for the first time?

Evaluation of intimacy

In order to verify hypothesis 3, we evaluated the intimacy to the robot depending on whether or not the participants would tend to perform actions that resemble an intimate relationship with the robot. The ultimate goal of this research was to make robots social entities, that is, to make it possible for robots to interact with humans on an equal position, such as developing friendship with a human. Assuming such a society, some items were set as actions requiring a degree of intimacy in dealing with the robot.

First of all, in order to clarify the relationship between these items and the degree of intimacy, we asked 23 members of our laboratory with the nine levels of Likert scale about the degree of intimacy necessary for wanting to perform the action. The result of the factor analysis on the questionnaire is shown in Figure 4. We listed three items, "Listen to her", "Be friends with her", and "Speak to her", which has high load in the first factor as the low social bonding and two items, "Invite her to my home" and "Live with her", which has high load in the second factor as the high social bonding. With regard to "Exchange contacts with her", the load of the first and second factors were 0.353 and 0.474, which were closer than those of the other items, so they were omitted from these two items. By using the low/high social bonding items, we investigated robot's appropriate expressions according to the degree of intimacy.

RESULT

The results of the questionnaire are shown in Figures 5 to 7. The graph shows the average value for the evaluation in each item, and the error bar shows the standard error. For human likeness, sociality, and intimacy, comparison of the three conditions (NS, NDS, and DS) was carried out by one-way analysis of variance, and multiple comparisons were performed using the Tukey HSD method. The results of multiple comparisons are shown in the figures.

Recognition of robot's facial expression and degree of pleasantness/unpleasantness

In order to compare the degree of pleasantness/unpleasantness felt from the expression of the robot and the degree of pleasantness/unpleasantness if the participant was in the place of the robot, we conducted a 2x3 mixed factorial ANOVA with 'position' (robot/participant) as a within-subjects factor and 'condition' (NS/NDS/DS) as a between-subjects factor (Figure 5). As a result, the main effects of position factors ($F(1,45)=13.060$, $p<.001$) and interaction ($F(2,45)=4.488$, $p<.05$) are significant. As a result of the simple main effect test using the Tukey HSD method, the difference between NS, NDS, and DS conditions is significant for the degree of pleasantness/unpleasantness of the robot (both $p<.05$). This

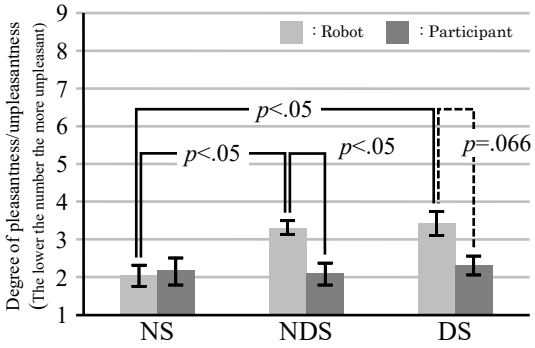

Figure 5. Degree of Pleasant Feeling in the Position of Robot/Participant

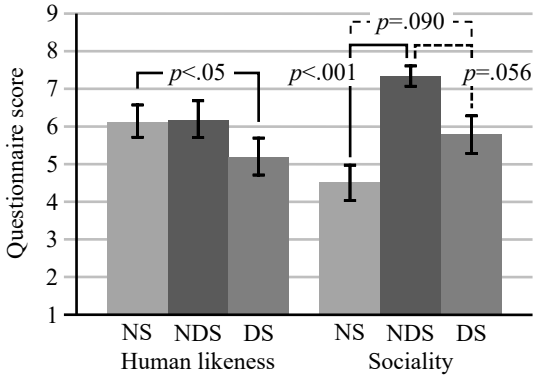

Figure 6. Evaluation of Human Likeness and Sociality

shows that there is a possibility that the NS condition gave the impression that the robot felt more unpleasant compared to the other conditions. Indeed, according to the freely expressed descriptions concerning facial expressions of the robot, in the NS condition, all 16 participants answered that she exhibited unpleasant facial expressions, whereas only 6 people out of 16 in the NDS condition answered that she exhibited a facial expression suppressing unpleasant emotions. In the NDS condition, there is a significant difference between the degree of pleasantness/unpleasantness of the robot and the degree of pleasantness/unpleasantness if the participant was in the place of the robot (p<.05). As described above, the participant received an impression of the facial expression that suppressed unpleasantness, and the degree of unpleasantness felt from the facial expression of the robot may be different from the degree of unpleasantness if they were in the place of the robot; therefore, the facial expression of NDS may be recognized as deception. In the DS condition, the difference between the degree of pleasantness/unpleasantness of the robot and the degree of pleasantness/unpleasantness if the participant was in the place of the robot showed a significant trend (p=.066). From this result, it is considered that the participants felt some degree of deception related to the smile of the DS condition compared to the NDS condition. In the DS condition, the facial expression of the robot was exactly the same for both the interlocutor and the participant. However, according to the free description, the facial expression towards the participants was recognized as an unpleasant facial expression as same as NS and NDS conditions, while the facial expression of DS for the interlocutor was correctly recognized as a smile. This recognition was common for all 16 participants in DS condition. After the experiment, when they looked again at the DS facial expression of the robot, they realized that it was a smile for the interlocutor, and they were surprised that the same facial expression was expressed to them. Because of the reason for the expressions, all participants mentioned in the DS condition that they observed a negative emotion; the context of the task seems to have influenced the recognition of facial expressions. The relationship between recognition of the robot facial expressions by the participants and experimental results is discussed in "DISCUSSION" section.

Human likeness

Although the main effect is a significant trend (F(2,45)=3.017, p=.059) as a result of the analysis of variance for the evaluation of human likeness (Figure 6), multiple comparisons show that the NS condition exhibits a more human-like impression of the robot than the DS condition (p<.05). This result means that the unpleasant expression of the eyes and mouth corresponding to the unpleasant situation contributes to an impression of higher human likeness than the pleasant expression, thereby supporting hypothesis 1.

Sociality

The main effect is significant (F(2,45)=10.213, p<.001) as a result of the analysis of variance for the evaluation of sociality (Figure 6). Multiple comparisons show that the NDS condition gives a higher sense of sociality than the NS condition (p<.001), the DS condition tends to give a higher sense of sociality than the NS condition (p=.090), and the NDS condition tends to give a higher sense of sociality than the DS condition (p=.056). This means that the NDS and DS conditions expressing the pleasantness of the mouth that is not corresponding to an unpleasant situation contribute to the sense of sociality. Therefore, although this result mostly supports hypothesis 2, it cannot be conclusively determined that the pleasantness/unpleasantness of facial expression of the eyes is irrelevant to sociality, because the NDS condition tends to give a higher sense of sociality than the DS condition.

Intimacy

For the low and high social bonding items, the average score of each item is calculated and compared in accordance with the conditions. The results are shown in Figure 7. As a result of the analysis of variance on the low social bonding items and multiple comparisons, the main effect was significant (F(2,45)=6.741, p<.01) and it was found that the NDS condition (p<.01) and DS condition (p<.05) give intimate impressions compared to the NS

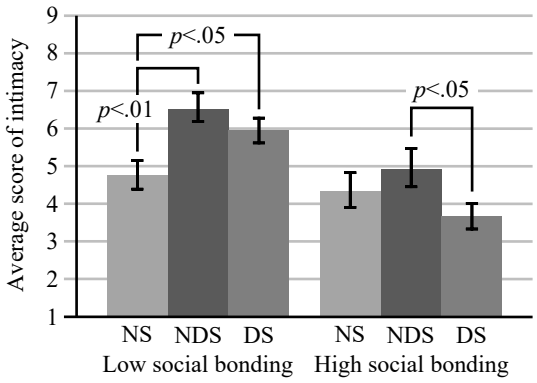

Figure 7. Evaluation of Intimacy

condition. This result implies that regardless of the pleasantness/unpleasantness of the expression of the eyes, the pleasant expression of the mouth contributes to an intimate impression, which supports hypothesis 3 in a limited way.

As a result of the analysis of variance on high social bonding items and multiple comparisons, the main effect was significant ($F(2,45)=3.400$, $p<.05$) and it was found that the NDS condition gives a more intimate impression compared to the DS condition ($p<.05$). This result implies that expressing the unpleasant expression of the eyes corresponding to the unpleasant situation, when the mouth expresses a pleasant expression, leads to an intimate impression. Although there is no significant difference, it can be seen that the average value of the NS condition, which is an unpleasant expression wherein the eyes and mouth correspond to the situation, is higher than that of the DS condition. In hypothesis 3, it was predicted that the DS condition expressing a pleasant expression on both the eyes and the mouth would give an intimate impression; however, in the high social bonding items, in contrast, there is a possibility that an unpleasant expression of the eyes corresponding to the situation gave an intimate impression.

DISCUSSION

Recognition of robot's facial expression and degree of pleasantness/unpleasantness

In all conditions, the participants recognized the robot's expression as an unpleasant expression however, the recognition of the degree of unpleasantness differed between the conditions. Regarding the unpleasantness of the robot recognized by the participants, the NS condition was recognized as the robot expressing strong unpleasantness compared to the NDS and DS conditions. Therefore, there is a possibility that the unpleasantness of the robot was evaluated based on the presence or absence of the unpleasant expression of the mouth.

In the NS condition, because the degree of unpleasantness judged from the facial expression of the robot and the degree of unpleasantness exhibited if the participants were in the place of the robot are almost the same, it is possible to give an irascible impression without trying to conceal unpleasantness. Indeed, when the participants who experienced the NS conditions were asked about the kind of impression they got about the robot, they answered, "Person whose emotion shows easily on the face" or "Very emotional person". On the contrary, in the NDS condition, because the degree of unpleasantness exhibited if the participants were in the place of the robot is higher than the degree of unpleasantness judged from the facial expression of the robot, there is a possibility that the participants felt more tolerant towards the robot not expressing unpleasantness. In the DS condition, which involves expressing a smile completely without expressing the affective expression, it was expected that the difference between the unpleasantness judged from the facial expression of the robot and the unpleasantness if the participants were in the place would appear more conspicuously; however, the difference is a significant trend. According to the interview, 3 out of 16 participants who experienced the DS condition said that they did not know what Minami was thinking. Although the facial expression of the robot was recognized as an unpleasant one in the DS condition, because the robot was actually smiling, it appears that the degree of the unpleasantness of the robot was more difficult to estimate than in the other conditions. There is no such opinion present in the NS and NDS conditions. There is a possibility that this can be an important clue toward judge unpleasantness of the robot with recognition of facial expressions, although wrinkles between brows, which is an expression based on the affective expression in NDS conditions, was smaller than the changes of the mouth based on the social expression.

Thus, there is a possibility that the degree of unpleasantness judged from the facial expression of the robot and the impression of personality judged therefrom influenced the evaluation of human likeness, sociality, and intimacy. We consider the following evaluations.

Human likeness

The NS condition gave a higher sense of human likeness compared to the DS condition. As described previously, this is because in the NS condition, the degree of unpleasantness judged from the facial expression and the degree of unpleasantness if the participants were in the place of the robot are almost similar and the participants recognized that the robot felt unpleasant the same as themselves. On the other hand, in the DS condition, it was difficult to estimate the degree of unpleasantness of the robot; therefore, it appeared that the sense of human likeness decreased.

Sociality

The NDS condition gave a higher sense of sociality compare to the NS condition. In the NDS condition, because the degree of unpleasantness if the participants were in the place of the robot is higher than the degree of unpleasantness judged from the facial expression, there is a possibility that the participants felt tolerant of the robot not

expressing unpleasantness and felt more sociality than that in the NS condition, which expressed an irascible impression.

Although the NS condition showed the highest value for human likeness, the average is nearly equal to that of the NDS condition. Furthermore, since the NDS condition also had the highest value for sociality, the robot that expressed affective and social emotions was able to exhibit a sense of human likeness and sociality.

Intimacy

We anticipated that the social expression, which expresses pleasant expression in social situations such as first meetings, gave an intimate impression. However, the tendency of the result is different between the low and high social bonding items. In the low social bonding items such as "I want to be friends", the NDS and DS conditions, which express social expression by the pleasantness of the mouth gave a more intimate impression than in the NS condition. Because not only the DS condition, but also the NDS condition gave an intimate impression, in situations requiring sociality such as the task set in this research (the situation of the first meeting), it is considered that regardless of the affective expression of the eyes, the social expression of the mouth exhibits an intimate impression.

On the other hand, in high social bonding items, the NDS condition gave a more intimate impression than the DS condition. Although there was no significant difference, the NS condition ranked higher in the evaluation of intimacy compared to the DS condition. For the DS condition, some of the participants, who had the impression that they did not know what the robot thought, also said that this impression affected the evaluation of intimacy. The DS condition expressed a social smile without the affective expression; therefore, it was impossible to infer the emotion of the robot. It is therefore possible, that the participants may have received the impression that it was hard to get into a deep relationship with the robot, to accomplish high social bonding items.

In addition, for the evaluation of intimacy, the evaluation of NDS condition is the highest in both the low and high social bonding items. From these results, robots that express facial expressions based on the affective and social expressions can exhibit a more intimate impression than robots that express either of the two emotional expressions.

Limitations and future work

In this research, in order to design the affective expression and the social expression of the robot based on voluntary / involuntary human facial muscles, we used the robot that looks human and has various actuators corresponding to human facial muscles on its face. It was suggested that this robot can offer an intimate impression to a human by using both the affective and social expressions; however, this result cannot be applied to all existing robots. For example, in the case of a child robot or a pet robot, it is expected that the affective expression gives a better impression than the social expression. The remaining issue is to clarify how emotional expressions should be used in accordance to the appearance and purpose of the robots.

The emotional expression is not limited to facial expressions. There are various modalities in which emotion voluntarily or involuntarily appears, such as the prosody of voice, gesture, or gaze. Further, the task to clarify whether an effect like NDS can be obtained even when the affective / social expression is performed in different modalities remains to be studied.

CONCLUSION

In this research, we proposed a new emotional expression combining involuntary facial expressions based on emotion (the affective expression) and voluntary facial expressions based on sociality (the social expression) with the aim of recognizing robots as social presence. We conducted an experiment to evaluate the impression of the robot that expressed emotion by the proposed method and that of the robot that only expresses emotion based on either one of the two mentioned expressions. The experimental results suggested that the affective expression contributes to a sense of human likeness and the social expression contributes to a sense of sociality, and that the proposed method that involves expressing emotions by both emotional expressions received a high evaluation in both parameters. Furthermore, in regard to giving an intimate impression to a human, it was suggested that the social expression is effective when performing acts that do not require high social bonding, such as becoming friends; however, the affective expression is necessary for acts that require high social bonding, such as living together.

Most existing social robots that interact with humans use only one of the emotional expressions. The result of this research suggests that it is necessary to effectively and appropriately use emotional expression depending on the partner and situation, in order for a robot to interact socially with a human. This is a kind of "sensitive to the situation" function, and is considered to be a necessary function for the robot to be accepted as a social presence. We expect that this research will encourage studies on emotional expression of robots and will promote the social advancement of social robots.

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