Trust towards the Robot with the Presence and Absence of Confidence

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Abstract. With the increasing presence of social robots in various circumstances, there is a great need to adapt robots' behaviors to the needs of the individuals they interact with. Expression of confidence is one important capability in either interpersonal or human-robot interaction. In this study, volunteer subjects engaged in 2 phases involving a social robot Kebbi. In the Perceptive Phase, participants watched several videos showing the robot's confident or unconfident expressions with different settings to pinpoint the factors of confidence expression including voice, motion, and response time. In the Game Phase, participants finished four sections of a treasure hunt game with support from the robot. In this phase, the robot gave hints while showing different combinations of confident/unconfident utterances and non-verbal information to explore how the robot's expressions consisting of verbal and non-verbal factors affect people's trust. Results have shown that both verbal and non-verbal factors are essential for people's estimation of the degree of the robot's confidence and participants tended to evaluate the robot with non-verbal information as more trusting and are more likely to trust the robot again after mistakes. This study provides insights into how advanced social features, like confidence, can be used to improve human-robot interaction.

Keywords: Expression of Confidence, Trust towards Robot, Human-Robot Interaction

1. INTRODUCTION

Robots are making advance in various domains, and they are especially becoming more common in social and educational fields of application, for example, there has been much research on how robots can be used in the classroom in order to facilitate, improve and support the learning process [1-4]. In Human-Robot Interaction (HRI), numerous studies have shown that expressions of a robot facilitate human understanding of the robot's behavior, affects, rationale, and motives, and are significant to make people perceive a robot as more life-like, trustworthy, and reliable [5, 6]. This trend is increasingly accompanied by the application of features of interpersonal social interaction in robot design [7].

From a human-centered point of view, there are various advanced social features deserving close attention in HRI. Particularly, research has shown that presence or absence of confidence can promote more natural interaction for people because it enables the transfer of scripts that are well known in interpersonal interaction [8, 9]. And confidence is proven essential in HRI, for instance, when robots learn knowledge from humans, confident/unconfident expressions are useful for robots to confirm the obtained knowledge [6, 10]. Meanwhile, it is supposed that user's expectations could be lowered if a robot can show expressions of confidence accordingly. Particularly, given that trust is the foundation of both successful human-human and human-robot collaboration, study has shown that it is potential to alleviate the loss of trust in the event of a robot failure if a robot gives unconfident answer [6]. Not only building up, but also for the purpose of sustaining and regaining the relationship between human and robot, it seems necessary to investigate people's impression of a robot that can show the presence or absence of confidence depending on different scenarios considering that the decrease in trust and reliability towards the robot in HRI may be suppressed in this way.

The previous work performed on humanoid Pepper has attempted to design the robot's expression of confidence [10]. It aims to figure out the problem that what factors influence people's understanding of whether the robot is confident or not. Consequences have shown that several essential factors based on human behavior including utterance speed and volume, spending time before the answer, and head rotation are respectively useful for people to estimate the robot's expressions of confidence and diffidence. However, there is currently no comprehensive study of how to

use the combination of those aforementioned factors to make a social robot express the presence and absence of confidence. It is also unclear that whether using different combinations of these factors are more understandable for people. And if so, how a social robot's confident/unconfident expression influences individual trust of the robot remains unexplored. Such exploration deserves more attention because the inappropriate design of social robot's expressions may lead to counterproductive and unintended effects, and especially, a decreasing trust towards robots will impedes the prosocial behavior a lot [11, 12].

Drawing upon two strands of research into the social robot, this study attempts to analyze how a robot using expressions to show presence or absence of confidence influences people's trust towards it. There are two parts in our study: the first part aims to figure out what combination of factors can effectively and evidently make people differentiate the confident expressions of the robot using some videos showing different robot's designed expressions; the second part investigates how robot's expressions with the presence or absence of confidence based on the consequences in the first part influence one's trust towards the robot by conducting a game with a social robot's support. In the game part, there are four sections showing different expressions of the robot and the settings of robot are following the parameters used in the first part which have referred to our related previous studies, including the verbal information: utterance speed, sound pressure (volume); the non-verbal information: spending time before answering (response time), head angle (pitch and yaw) [6, 10]. Results have shown that participants could distinguish the robot's expression of confidence using designed verbal and non-verbal factors, and the presence of confidence influences participants' trust towards the robot. Comparing with related previous works, this study has gone further on the design of expressing robot's presence and absence of confidence using the combination of verbal and non-verbal factors and extended the application to different kinds of social robots. Our study also makes a major contribution to research on trust towards the robot with the presence and absence of confidence.

The paper has addressed effects on perceptual aspects of expressions of the robot based on verbal and non-verbal factors. Furthermore, consequences are useful in expanding our understanding of the influence of the robot's confident expression on individual trust. We stress that this is an important contribution to the expression of robot confidence involving verbal and non-verbal factors. In the long term, it provides insights into the expression model of the robot involving advanced social factors for more complicated situations. The paper has been organized in the following way. Section 2 provides more information of related works. The setup of the experiments in two parts are described respectively in Section 3. The results of the experiment in each part and corresponding discussion are shown in Section 4. Section 5 is the summary and future perspective of this study.

2. RELATED WORKS

2.1. Robot's Confidence Expression

Confidence is one significant social factor. Understanding of other's confidence degree is essential in social interaction because it can reflect one's characteristics and internal state. Therefore, it can be helpful to develop an appropriate strategy for the robot to meet one's needs in in different scenarios. Some studies of people's expression of confidence have shown that a speaker having confidence in the content speaks with louder voice and lower latency compared to the state of having no confidence [13]. Another study has figured out that increased speech rate, falling intonation, and lowered pitch cause the listener's perception that the speaker is more confident [14]. Also, when the speaker's voice express high confidence, the mean intensity, and intensity variation of voice increase and the utterance duration decreases compared with that of low confidence [15]. Considering the research of non-verbal factors, speaker's eyes, facial expressions, and head movements as visual cues are more used for judgment of the speaker's confidence level by observers [16]. Therefore, it is assumed verbal information and head motion are important features to estimate one's confidence for human beings.

Some works in HRI have shown the importance of expressing confidence, for instance, one research has reported that participants indicated that the robot was not so happy because the robot did not praise and encourage him when he made a correct action in an imitation game [5]. In addition, studies have shown that the robot's expressions can be more understandable by using verbal and non-verbal features [17, 18]. Social robots are thus necessary to express confidence using verbal and non-verbal information instead of merely using the utterance information. It has been verified that non-verbal information is useful for a robot to convey intentions [19]. When a robot is making potential suggestions, the strategy that uses non-verbal information to make uncertain statements shows potential to create natural and smooth interaction.

In our previous work, the expression design of the humanoid robot Pepper for showing confidence or diffidence using verbal and non-verbal was proposed [10, 20]. There were 4 stages including collecting data from human; extracting features of expressing presence/absence of confidence; applying features on Pepper; evaluating Pepper's confidence level. To be

specific, in the first stage, to create different degrees of the robot's confidence, we firstly collected the data of eight individuals. All participants were asked to answer a question shown by robot Pepper, and then they needed to evaluate the confidence level of their answers with the scale from one to five. A microphone was used to obtain participants' data of voice while Microsoft, Kinect v2 was used to obtain the data of head motion. There were 48 different questions for each participant. In the second stage, we extracted the effective values of collected data and analyzed the difference between the states of being confident and unconfident. It was shown that sound pressure, utterance speed, spending time before the answer, and head angle including pitch and yaw were the essential features to express presence/absence of confidence. In the third stage, we applied the effective features on Pepper by once changing a feature while keeping defaulted values for other features as one comparison. Then we took videos of the robot answering 8 different questions which performing the changed feature. Subsequently, five participants who did not participate in the stage of data collection were recruited to rate the confidence level (being confident, neutral, and unconfident) by watching all comparisons of videos of Pepper's expressions. Results proved that all features could be the clue for estimating robot's confidence level but features required for estimation were different among different individuals. However, there are some problems remain unexplored. For example, whether the combination of the features can make the robot's expression of confidence more understandable, and can these features be effectively applied on other types of social robots.

2.2. Trust Toward Robots

Human trust towards robots is a fascinating and central topic in HRI. Without appropriate trust, robots cannot be widely accepted in daily life use. In this respect, trust is essential when robots are into the human social environment [21]. Due to the variety of HRI scenarios, there are different methods measuring trust. A subjective measure using a rating scale appears to be a simple and straightforward approach that has been used successfully in various domains [21].

Social robots should be capable of fostering human trust through strategies of interacting with humans at the appropriate level or even should regain trust in some specific circumstances. One study has observed that a robot that expresses social cues can make participants trust it more in a critical task [22]. Moreover, robot's performance has been found to have the greatest influence on trust [23]. It is significant to understand how robot's expressions influence the trustfulness and then develop strategies to sustain the trustfulness when dispiriting performance appeared. Research has shown that recreating human motion on non-human platforms to create movement understandable to humans may increase trust in these systems [24]. Besides, evidence has suggested a relationship between voice pitch and trust towards the embodied agent [25]. It has also shown that the robot's expression of confidence based on the verbal information could be helpful to maintain the trustfulness after the robot making a mistake [6]. However, to the best of our knowledge, there has been little discussion about how verbal and non-verbal features performed by a social robot might affect individuals' trust towards it.

3. EXPERIMENTAL SETUP

In this study, a video-based experiment was firstly conducted named as Perceptive Phase and the game with a real robot using a task of treasure hunt was performed named as Game Phase. The results were collected respectively from the corresponding post-test questionnaires in two phases.

We used robot Kebbi that measures 318mm x 307mm x 166mm; has a 7-inch touch display on the face part and 12 degrees of freedom throughout the body with neck and arm motions in two experiments [26, 27].

3.1. Subjects

In Perceptive Phase, 8 male students came from technical backgrounds in the university whose ages ranged from 21 to 28 (M = 23.5, SD = 2.8) were recruited for this experiment. Their mother languages are Japanese (N = 4) and Chinese (N = 4).

In Game Phase, 6 male students including 3 Japanese and 3 Chinese in the university aged from 22 to 27 (M = 23.8, SD = 1.9) took participated in the treasure hunt game. And all participants in this phase were different from those in Perceptive Phase. All Chinese participants in two phases can understand Japanese well.

3.2. Robot Expression Settings in Perceptive Phase

We firstly conducted a recognition experiment that was a pure perceptual task without an interaction context by watching videos of the robot Kebbi.

Eight expressions were created for the robot by combining two states (confidence: w, without confidence: w/o) for each of the three elements including the voice, motion, and response time. The voice settings of robot Kebbi consisting of values of voice speed and sound pressure, were set referring to the previous study performed on the robot Pepper. Results have verified that both the voice speed and sound pressure of the robot with confidence (w) should be larger than those without confidence (w/o) when these two factors are set as congruent [10]. The

motion settings including the angles of pitch and yaw of head orientation were obtained based on the analysis of people's expressions of confidence when answering questions by capturing the corresponding features of the head motion using Microsoft, Kinect v2 in the former works [10, 28, 29]. Results have shown that when someone is not confident, he or she is less likely to face the screen by moving the head before answering [10]. Furthermore, evidence has shown that the time before answering a question can negatively affect the impression of the robot if the waiting time is too long in human-robot interaction [30]. Taking these results into consideration, we set the response time as 1 second for the state of confidence (w) and 2 seconds for the state of without confidence (w/o).

Details of the attributions in these two states (w, w/o) are shown in **Table 1**. And **Table 2** shows the settings of eight kinds of robot expressions created by combining two states (w, w/o) for each of the three elements: voice, motion, and response time, numbered from ID1 (w for all elements) to ID8 (w/o for all elements).

Each subject was asked to watch 10 videos. **Fig.1** illustrates the images of the robot Kebbi in videos. In each video, a robot gave an answer to a question with one of the created eight kinds of expressions, and the subject needed to estimate the confidence of the robot in 5 degrees from 1 (most unconfident) to 5 (most confident) after watching each video. In the first two videos, to make sure the subject knows the range of

Table. 1 Attributions of two states: confidence (w) and without confidence (w/o)

State	Verbal		Non-verbal		
	Voice		*Motion*		*Response time*
	sound pressure [a]	*speed* [a]	*head pitch*	*head yaw*	
w	125%	105%	0°	0°	1 s
w/o	55%	70%	34.4°	26.5°	2 s

a. The default settings of the sound pressure and utterance speed of robot Kebbi are represented as 100%.

Table. 2 Settings of robot's expressions

ID	Voice	Motion	Response Time
1	w	w	w
2	w	w	w/o
3	w	w/o	w
4	w	w/o	w/o
5	w/o	w	w
6	w/o	w	w/o
7	w/o	w/o	w
8	w/o	w/o	w/o

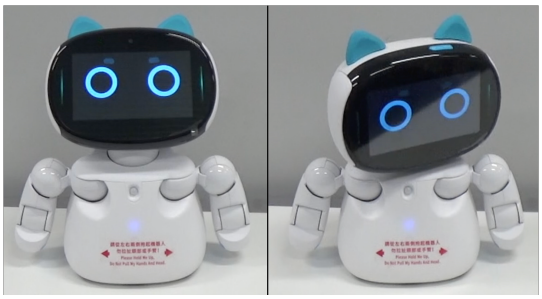


Fig. 1. Images of the robot Kebbi

the robot's expressions of confidence, two videos that showed the settings of w for all elements (ID1) and w/o for all elements (ID8) were randomized demonstrated for each subject. The following 8 videos were used for collecting the results of the estimation of robot's confidence level. The order of the 8 videos was randomized for each subject as well. In addition to the required question of the judgement of robot's confidence, participants were also encouraged to write down the reason of their estimation as the optional question.

3.3. Experimental Procedures in Game Phase

A treasure hunt game was used in Game Phase. In this game, there were three sand mountains displayed on the screen of a laptop and one of them contained the treasure. The participant was seated at a table, on top of which was a laptop in front of them and the robot Kebbi on the left side. Firstly, each participant was asked to read the instruction manual of the experiment that described the process of the experiment, the rules of the treasure hunt game that selected one of the sand mountains behind which he thought there was the treasure, and the number of correct selections in the formal trial would decide if one can get some sweets. The sweets were prepared as the reward to encourage the participant to achieve a high score. They were told that the robot Kebbi would make a prediction as a hint before their selections, but the robot's prediction may be right or wrong, so they could ignore or accept the robot's prediction. Participants were then asked to complete a demographics survey.

The treasure hunt game was designed under two conditions: one condition where the robot expressed verbal and non-verbal information (with non-verbal information) and the other condition where the robot only performed verbal information (without non-verbal information). And there were two types of robot utterances: confident and unconfident predictions. Two-thirds of confident predictions were correct, and one-third of unconfident predictions were correct. Except that "maybe is" was used in the unconfident predictions while "is" was used in the confident

predictions, there were no other difference between two types of utterances. Each participant finished 2 (utterance) × 2 (condition) sections. Considering the order effect, 3 participants started from the condition with non-verbal information, and the remaining 3 people started from the condition without non-verbal information. The numbers of accepting robot's hints in both practice and formal trial were collected.

Each participant would start the practice trials and formal trials of the treasure hunt game under the attributed condition and then answered the post-test questionnaire of the trust toward the robot. There were 12 times of selections (6 with confidence, 6 without confidence) in the practice trial, while 24 times (12 with confidence, 12 without confidence) in the formal trial. In the practice trial, the answer of which sand mountain contained treasure would show after the participant's prediction. In addition, in the practice trial, the unconfident utterance with a wrong prediction was always performed in the first two questions. For the next following question, the robot demonstrated the confident utterance aiming to examine that whether using confident utterance can be a tool to increase trust towards the robot. The answer of each selection would not show in the formal trial considering that the trust of the robot may fluctuate depending on the robot's failure or success because of the feedback of the right answer during the formal trial. The treasure hunt game in practice trial and formal trial displayed on laptop are illustrated in **Fig.2**.

In Game Phase, the parameters summarized from the results in Perceptive Phase were utilized. To be specific, in the condition with non-verbal information,

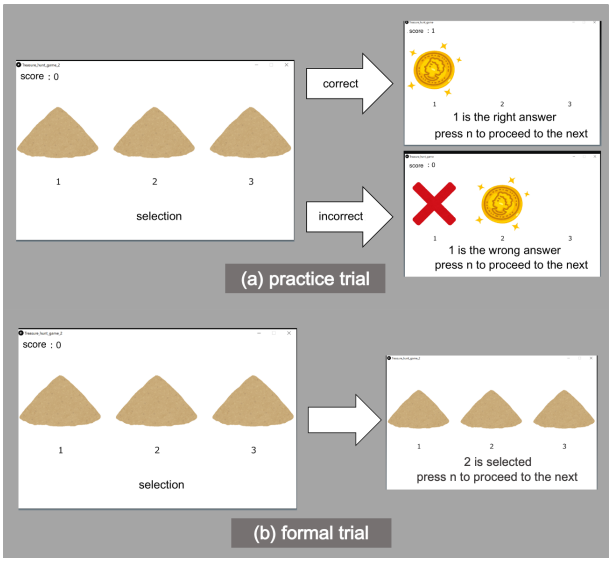


Fig. 2. Illustrations of treasure hunt game

settings of ID1 (with confidence for all elements) were conducted on the robot Kebbi for the confident prediction while the parameters of ID8 (without confidence for all elements) were used in the unconfident prediction. On the other hand, in the condition without non-verbal information, the parameters of ID1 were always demonstrated. After finishing each section of the game, participants needed to answer a post-test questionnaire for evaluating the level of trust towards the robot which was rectified for our study based on the work by Sakumoto et al [31]. There are 10 items in this questionnaire using 7- point scales with the answer choice from 1 - "I disagree completely" to 7 - "I agree completely". The details of

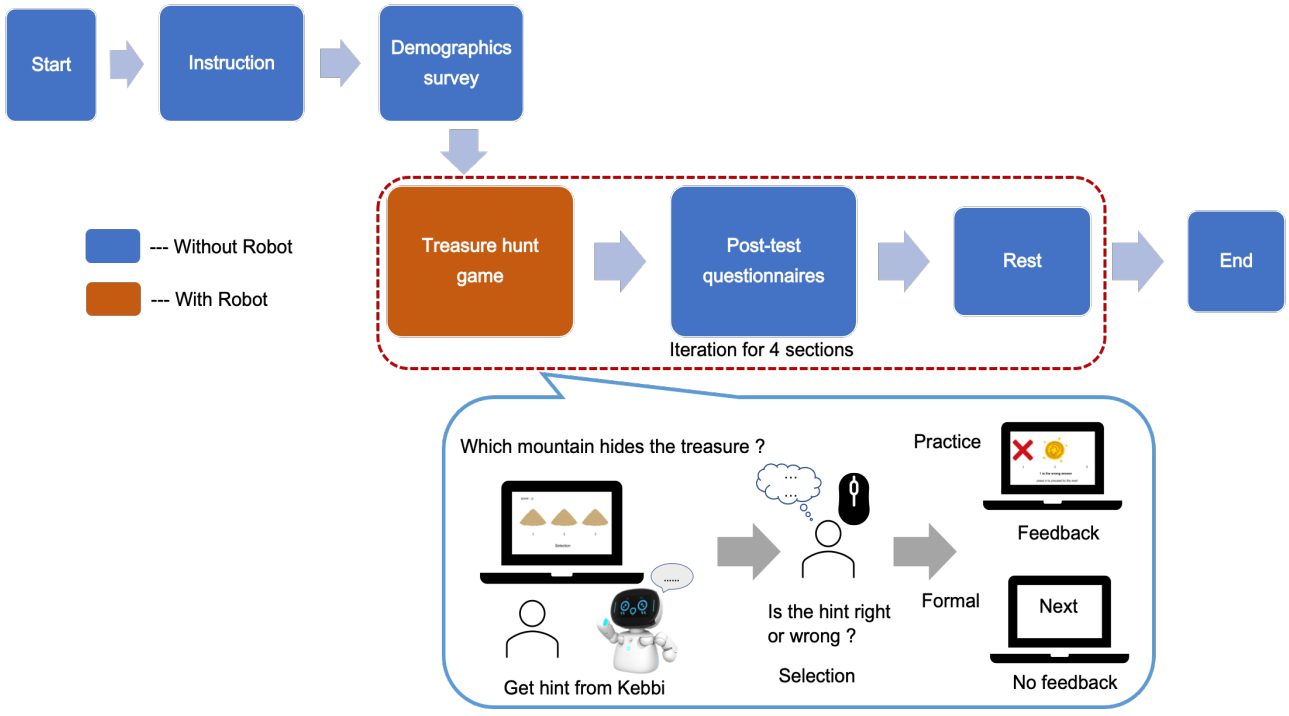


Fig. 3. Experimental process

the contents are shown in **Appendix A**. The whole experimental process of the Game Phase is demonstrated in **Fig.3**.

4. RESULTS AND DISCUSSION

4.1. Results in Perceptive Phase

We have investigated the results of the estimation of robot's confidence level in Perceptive Phase by calculating the average value of eight kinds of robot expressions from all participants' questionnaires after watching eight videos. Results are shown in **Table 3**. To make sure which of the elements including voice, motion, and response time is the reason for participants' estimation of the robot's confidence, only those pairs of ID that there was only one different state between the settings of voice, motion and response time were compared. And we calculated the number of times that the average value of estimated confidence was greater than the comparison that was with the larger ID. Therefore, there were 4 times of comparison for each element. Results that meet the aforementioned condition are as follows: for voice, there were 4 times; for response time, there were 3 times; for motion, there was 1 time. It can be summarized that the difference in voice and response time could express the presence or absence of confidence of the robot. The reason why motion could not express the confidence in this experiment may be the speed of head rotation. According to the participants' comments about the judgement from the questionnaire, some participants felt that the robot seemed confident when the rotation speed of its head was high. In fact, for the pairs where the only one different state between the settings of ID was motion, the pair of ID1 and ID3, and the pair of ID5 and ID7, the degree of confidence was estimated to be equal or higher when the setting of motion was w/o, while for the pair of ID2 and ID4, the average value of estimation was lower when the setting of motion was w/o. It is supposed that the rotation speed of head seems to be an important factor to convey the presence or absence of confidence when considering the elements of motion. However, the pair of ID6 and ID8 did not follow this rule on robot Kebbi. The mutual effect of the factors of confident/unconfident expression deserves more exploration in the future research.

Table. 3 Average value of confidence estimation of all kinds of expression

ID	Average Value of Confidence
1	4.0
2	4.1
3	4.0
4	3.8
5	3.0
6	2.0
7	3.8
8	2.9

Table. 4 Value of each subject's confidence estimation of w for all elements (ID1) and w/o for all elements (ID8)

Subject	Value of Confidence	
	ID1	***ID8***
A	3	2
B	5	2
C	4	4
D	4	4
E	3	3
F	3	2
G	5	3
H	5	3

In addition, to determine robot's confident expression, we compared two states that all elements are present and absent. **Table 4** shows the specific values of the confidence estimation for the settings of w for all elements (ID1) and the settings of w/o for all elements (ID8) from each subject labeled A through H. There were 5 subjects who estimated the confidence of the expression of ID1 higher than that of ID8. Conversely, no one estimated confidence level of the expression lower than that of ID8. In summary, it is considered that the presence or absence of confidence can be expressed by using the settings in these two expressions. Furthermore, considering the results in the previous study which conducted on humanoid robot Pepper, it is supposed that this paradigm of robot's expressions of presence or absence of confidence could be shared in these two different types of social robots [10].

4.2. Results in Game Phase

The average values for the answer of 10 items in the questionnaire of trust towards the robot were calculated. We compared the results when the robot performed verbal and non-verbal information simultaneously, and when it only carried out verbal information. **Table 5** shows the number of times the prediction from the robot under the conditions with non-verbal information and without non-verbal information were accepted in the formal trials, and the corresponding average values of the questionnaire of trust towards the robot for each participant labeled A to F. As shown in **Table 5**, the average value of the questionnaire over all participants in the condition with non-verbal information is 0.3 higher than that in

Table. 5 Number of acceptance and average value of trust towards the robot in each condition

Subject	With Non-verbal Information			Without Non-verbal Information		
	Acceptance number		*Average value of trust*	*Acceptance number*		*Average value of trust*
	ID1	*ID8*		*ID1*	*ID8*	
A	12	5	5.8	12	2	5.3
B	12	12	4.4	12	10	5
C	12	6	4.1	10	7	3.8
D	10	5	4.9	9	4	4.2
E	12	7	5.7	12	8	5
F	10	2	4.8	12	10	5
Mean	11.3	6.2	5.0	11.2	6.8	4.7

the condition without non-verbal information. Meanwhile, regarding the number of times of acceptance, in the condition with non-verbal information, for the settings of ID1, when the robot was using confident utterance, the average value is 0.1 higher than that in the condition without non-verbal information, and for the settings of ID8, when the robot was using unconfident utterance, the average value is 0.6 points lower than the corresponding one without non-verbal information. However, no significant difference is shown in both the average value of the questionnaire and the number of times of accepting the robot's proposal between these two conditions.

On the other hand, to explore the potential ways for regaining the trust towards the robot when mistakes happened, we have also analyzed the results from the practice trial where participants knew that robot had given the wrong prediction from the feedback. We have paid attention to whether robot's confident expressions are more acceptable after two consecutive failures with the unconfident prediction when trust towards the robot tends to be weaken. In summary, four subjects accepted the robot's predictions under both two conditions while two subjects accepted the robot's predictions only under the condition with non-verbal information. Hence, when utilizing robot's non-verbal information, the strategy of using confident utterance seems promising as a trigger for regaining people's trust towards the robot once trust has been reduced because of the robot's consecutive failure when using unconfident utterance.

5. CONCLUSION AND FUTURE WORK

This paper has focused on both the design with the presence or absence of confidence and the evaluation of trust towards the social robot. Experiments were conducted to examine the parameters of expressions to show confidence/diffidence and to verify the effects of the robot's non-verbal information on people's trust. The experimental results showed that the participants could differentiate between the robot's confident and unconfident expressions. It was also shown that their trust towards the robot with non-verbal information can be boosted in a game scenario. This paper contributes to the design of robots' confident expressions through verbal and non-verbal factors. Furthermore, consequence that trust towards the robot with non-verbal factors when showing confidence can be rebuilt indicates a beneficial effect of utilizing features of confidence in human-robot interaction.

One of our long-term goals is to apply these modeled expressions in real life, such as to improve students' performance in the educational scenario. For that purpose, more work in larger scope will need to be done considering the limited sample in the current study. Moreover, it is highly anticipated to utilize the level of confidence measured in real-time to make the robot adjust its behavior to increase the student's confidence level. Future studies regarding the use of external measurement devices, such as voice recognition, motion detectors, electroencephalographs (EEG), and heart rate monitor, would be worthwhile for reliable measurement of individual states.

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Appendix A. QUESTIONNAIRE ABOUT TRUST TOWARDS ROBOTS

No	Contents
1	This robot is superb.
2	Predictions from the robot show good results.
3	This robot is useless. *
4	This robot is satisfying.
5	I would like to comply with the predictions from this robot.
6	This robot's mistakes are unforgivable. *
7	This robot is trustworthy.
8	I want to play other games with this robot.
9	I feel tired when I am with this robot. *
10	I would like to ask this robot for advice in the same game again.
(∗Reverse Item)	