Investigation of Relationship Between Robot Expressions and Human Perception Considering Negative and Anxiety Scale

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Abstract. Perception is one of the most important capabilities in either interpersonal or human-robot interaction. To design the appropriate robot expression styles to gratify different types of people, a better understanding of the relationship between human perception and detectable personal physical and phycological features is essential. In this study, an online video-based questionnaire was utilized to investigate human perception of robot different emotional expressions based on various combinations of voice and motion traits. The negative and anxiety scale were chosen as the phycological indicators. Results have shown that robot's different expression patterns can elicit participant's different perceptions towards robot and participants are generally more perceptive about robot's voice trait than its motion trait. Meanwhile, significant negative correlation between anxiety of the communication capacity and the perception of the robot with negative motion and voice has strengthen the idea that it is necessary to take people attitudes towards robots into consideration in social robots' expression design. This study provides the first investigations into how to make robots generate appropriate reactions considering individual inner conditions.

Keywords: Human-Robot Interaction, Negative and Anxiety Attitudes, Human Perception

1. INTRODUCTION

As social robotic research advances, robots are improving their abilities to become more human-like [1]. To investigate social interactions between robots and humans, a natural approach is to design robots behave in reasonable responses through speech or body language according to the pre-defined styles. A significant challenge obstructing present progress is how to achieve harmonious communication between humans and robots. To address this, more and more research in the field of Human-Robot Interaction (HRI) has focused on adapting the behavior of a robot to the user it interacts with. The adaptation can be based on the personality of the user, the affective state of the user, or different body signals [2–4].

One thing which has always been ignored in related research is only what the robot intends to express can be accurately understood by human interlocutors, it can give sequential support and more meaningful responses for the human partner. However, a formal definition of social robots' expression styles remains unclear and different practitioners have defined it from different perspectives. Moreover, studies among different disciplines have heretofore failed to fully get through mechanisms of human cognition, making robots duplicate the mechanism of the human mind seem hopeless [5]. Additionally, the social signals are perceived as blunted when displayed by a virtual agent, regardless of whether its appearance was realistic or simple. And while parameters allow for sophisticated social expressions, a question emerges as to whether this is necessary, as people are already able to recognize intentional social signals from behavior patterns from a robot [6].

On the other hand, the relationship between the attitudes and anxiety towards robots and the mechanism of how people perceive robots' expression styles remains unexplored now. Although some research has substantiated that people's attitudes and emotions toward the robots can notably affect their behavior, the research is still insufficient when it comes to deciphering robot's expressions considering the task and individual circumstance [7, 8]. There is a sophisticated relationship between the type of robot or robot dialogue and the attitudes towards robot [9].

In this paper, different robot expression styles have been utilized to explore the influence of robot expression on human perception by using the Likert-scale method. The robot expression style is based on different motion (head and arm) and verbal features (pitch and speed). Given the hypothesis that there would be a gap among different people's perceptions because of personal mental states discrepancy, we have combined two attitudes scales (Negative Attitudes toward Robots Scale and Robot Anxiety Scale) which are psychological scales for measuring the mental states of users towards robots with the evaluation of robot expression styles to investigate their relationship [10, 11].

Our study attempts to find the corresponding relationship between the sensory profile of a participant including his/her perception and attitudes towards robots, and a humanoid robot's expression based on voice and motion changes. The obvious distinction of personal perceptions and attitudes among different participants emerges from the data, boosting the idea that the personalized robot with adaptive expressions is essential to meet individual needs. Results in this study are beneficial to construct an experimentally solid benchmark for adaptive robot expression design to maintain long-term interaction with the social robot in the future.

2. RELATED WORKS

2.1. Attitudes Toward Robots

An attitude is psychologically defined as a relatively stable and enduring predisposition to behave or react in a certain way toward persons, objects, institutions, or issues, and the source is cultural, familial, and personal [12]. This definition of attitudes implies that they can be affected by cultural backgrounds and personal experiences. Furthermore, based on the idea that changes in attitudes produce a corresponding change in thoughts and behaviors, results also imply that this rule applies to the situation when people interact with robots [13]. Therefore, we believe it is important to further investigate the influences of the features of attitudes and emotions on human-robot interaction because personal sentiment and perceptions can shape technology's assimilation.

2.1.1. Negative Attitudes toward Robots Scale (NARS)

Negative Attitudes towards robots tended to be associated with more negative evaluations of the behavior of robots with Socially Interactive behavior style [10]. This scale consists of fourteen questionnaire items and these items are classified into three sub-scales, S1: "Negative Attitude toward Situations of Interaction with Robots" (six items), S2: "Negative Attitude toward Social Influence of Robots" (five items), and S3: "Negative Attitude toward Emotions in Interaction with Robots" (three items). The number of grades for each item is five (from 1: I strongly disagree to 5: I strongly agree), and an individual's score on each sub-scale is calculated by summing the scores of all the items included in the sub-scale, with the reverse of scores in some items. Thus, the minimum and maximum scores are 6 and 30 in S1, 5 and 25 in S2, and 3 and 15 in S3, respectively. The details of the NARS questionnaire are shown in **Appendix A.1**.

2.1.2. Robot Anxiety Scale (RAS)

It is important to measure the anxiety towards robots because solving the problem prevents individuals from alienating interaction with robots in daily life [11].

Robot Anxiety Scale (RAS) was developed to determine human anxiety toward robots evoked in real and imaginary HRI situations. In contrast with the NARS, this scale aims to measure state-like anxiety that may be evoked by robots [11]. This scale consists of 11 questionnaire items classified into three sub-scales: S1; "Anxiety toward communication capacity of robots" (three items); S2, "Anxiety toward behavioral characteristics of robots" (four items); and S3, "Anxiety toward discourse with robots" (four items). Each item is scored on a six-point scale: from 1: I don't feel anxious at all to 6: I feel anxious strongly. An individual's score on each sub-scale is calculated by adding the scores of all items included in the sub-scale. Thus, minimum and maximum scores are 3 and 18 for S1, 4 and 24 for S2, and 4 and 24 for S3, respectively. The details of the RAS questionnaire are listed in **Appendix A.2**.

2.2. Human Perception of Robots' Expressions

Not only robot behavior will affect the interaction process, how people interpret interlocutors' physical changes through sensory systems is responsible for sustaining the long-term human-robot interaction [6].

For delectation in the interaction, if the robot can give a reasonable response during HRI, humans will not care if its interior system can obtain a very high accuracy [1]. Some studies have proven that personality adaptation by a social robot could positively impact towards improving user's task performance and was also able to encourage task performance and attention training, making people enjoy interacting with the robot more [14–16]. Hence, in addition to improving the algorithms used in the social robots' detection system, designing a favorable action response of social robots to address the current technological shortcomings is a possible solution. Furthermore, together with our previous studies, many studies have reported the effect of personal traits including user's gender, culture, personality, and other psychological features on how they perceive and interpret robots' expressions during the interaction [17–19]. Considering the distinct individual differences, it's necessary to design the social robot with different expressions that can be adaptive based on user characteristics. Studies that explore the effect of robot expression styles on human perception, engagement, and task performance, like what our work does, are essential.

3. EXPERIMENT SETUP

In this study, an online video-based experiment including a game with a robot and the post-test questionnaire. A task of spotting differences between two similar images has been chosen as it allows various answers of confidence degree and can be used as arousal and emotional stressor [20].

All participants needed to complete 7 sections in the same flow and submit each result of them through Google Form [21]. We recorded videos of a real robot's performance for the online survey to maximumly simulate the real human-robot interaction to investigate the perception of robot expression styles in realistic scenarios. The humanoid robot Pepper was chosen to perform these different expressions [22].

To explore relationships between attitudes and anxiety towards robots and people's responses in the online questionnaire, before the online game, all participants answered the NARS and RAS questionnaire to measure their attitudes towards robots.

3.1. Subjects

We recruited 23 participants for this experiment (Female = 8, Male = 15) from the university whose ages ranged from 21 to 29 (M = 24.04, SD = 4.65). Their mother languages are Japanese (N = 12) and Chinese (N = 11), and all of them come from technical backgrounds.

3.2. Robot Expression Design

Seven patterns of robot expression have been utilized going with seven sections in this experiment to investigate human perception of the robot. We use positive and negative states to differentiate the expression styles as they are the general standard for designing robot behaviors and basic dimensions of human emotional granularity [23]. The differences between the negative and positive states include the variation of speech tone and speed and different

movements. Given the consequences that people feel a robot weird when the emotional states of verbal and motion feature are contrary, for example, when the robot's motion was set as positive but its verbal feature is set as negative (a low tone or discouraging utterance), we didn't use the opposite motion and verbal attributions in this study to avoid cross-impact [24]. The corresponding relation of section number and expression style is described in **Table.1**. The demonstration of robot different motion styles is

Table. 1 Section Number and Robot Traits Match

Voice	Motion		
	Positive	**Normal**	**Negative**
Positive	3	7	
Normal	5	1	4
Negative		6	2

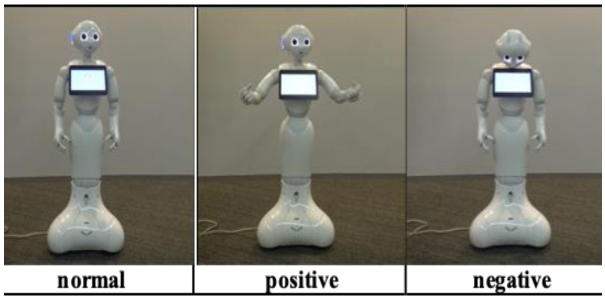

Fig. 1. Robot Motion Images

shown in **Fig.1** and details of robot verbal and motion traits are listed in **Table.2**.

Table. 2 Robot Expression Traits Setup

Attribution	State		
	positive	**normal**	**negative**
Verbal			
speed	100%	100%	80%
pitch	130%	100%	70%
Movement			
head	up	up	down
arm	open and waving	static	wrist rotation

3.3. Experimental Procedures

Before the first section, participants needed to fill in their basic personal information including name, gender, mother language and whether have the interaction experience with a robot or not, and then the participants finished the task in which they watched several short videos presenting the robot Pepper with whole body in default voice and motion settings. After finishing the first section as the control condition which showed the robot with the normal expression style to make participants be acquainted with the basic state of the robot, participants were suggested to finish the left sections in a random sequence to avoid order bias.

In the first section, a video firstly showed the robot greeting with participants, introducing the details of the spot difference game, and explained to the participant what they had to do in the experiments. The following game process was shared by 7 sections in the experiment. After preparing to concentrate on the game, participants were asked to observe each pair of images for utmost 1 minute to find the differences between them as much as possible. They were forbidden reviewing the images after the observation time. Then participants needed to watch a video showing the robot asking how many differences have been found and participants needed to answer by selecting the number ranged from 0 to greater than 4.

Multiple branches were designed in this part. If the participant had chosen a number from the range from 0 to 3, the online questionnaire would jump to one video showing the robot with the indifferent utterance (Well) while chose a number equal to or over 4, the questionnaire would jump to another video showing the robot with the complimentary response (Excellent.). Afterward, both the two different responses would be led to the same video showing the robot asking whether the participant was confident about her/his answer or not. Similarly, after selecting if he or she was confident about the found difference number, if the participant felt confident, the online questionnaire would jump to one video showing the robot with complimentary response (You've done a great job.) while the unconfident selection would lead to another video showing the robot with encouraging response (Don't worry, you could be right.). Finally, in the last part of each section, participants needed to fill in a questionnaire which was composed of the impression and likability towards the robot, the enjoyment of the game demonstrated in this section, the confidence degree about their answers measured on a scale from 1 to 7, and the game difficulty assessment based on their subjective feeling measured the scale from 1 to 5. The details of the post-experimental questionnaire are shown in the **Table. 3**.

Not until all seven sections had been finished, would participants be guided to an unfinished section with same procedure described in last paragraph. In section interval, the participants could have a rest whenever they needed. A video illustrating the robot said thanks and goodbye to the participant was shown after the last section had been finished. Once the participant submitted the questionnaire, the online experiment was regarded as accomplished. The whole online experimental process is depicted in **Fig.2**.

4. RESULTS AND DISCUSSION

4.1. Attitudes and Anxiety Scale Results:

Table. 4 Results of NARS and RAS Scores

Item	Mean	SD	Pearson correlation	
			gender	language
NARS-S1	10.30	2.74	0.15566	0.08622
NARS-S2	11.74	4.13	-0.04328	-0.17539
NARS-S3	5.39	1.85	-0.35932	0.12952
RAS-S1	11.09	3.64	-0.14597	-0.70756
RAS-S2	12.87	3.91	-0.38076	-0.28588
RAS-S3	11.13	3.76	-0.07560	-0.31820

Analysis of Standard Deviation and a between-subjects Pearson correlation calculation were conducted on attitudes and anxiety questionnaire results. The results shown in **Table.4** manifests the statistical results. A significant correlation between the S1 sub-scale in Robot Anxiety Scale and participants' mother language has been uncovered. To be specific, the participant whose mother language is Chinese felt less anxious about communication capacity of robots

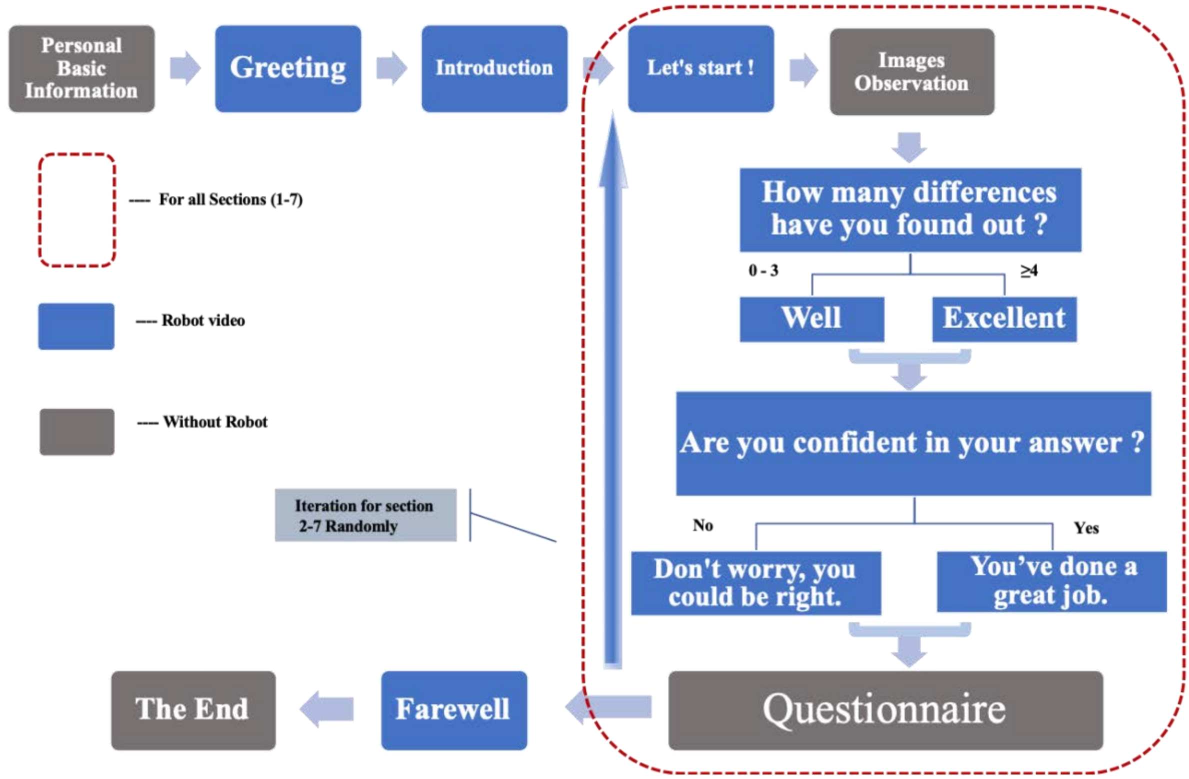

Fig. 2. Flow Chart of Experimental Procedure

(p-value < 0.05). However, except for that, participant gender, language (Japanese, Chinese), were found to be non-significant correlated with other scales and will not be discussed further in this paper.

4.2. Online Questionnaire Results:

For the online questionnaire, all of Pearson correlation values between two collected question answers have also been calculated. However, no significant differences have been presented for different gender and mother language groups this time. Given the commonsense, results of a negative correlation between the evaluation of confidence degree and game difficulty as well as the positive correlation between likability towards robot and enjoyment in all sections will not be discussed.

According to the correlation results in each section, the evaluation of positive image of robots is always positively correlated with people's Likability verifying the idea that participants prefer a robot with a positive image. At the same time, results have revealed that either the participant's confidence degree or the difficulty evaluation of the game itself doesn't influence participants' likability towards the robot and their enjoyment of the game. No other statistically significant correlation has been shown among other aspects.

To explore human perception towards different expression styles, we horizontally compared the results from each section and **Fig.3** illustrates the Box and Whisker charts based on each question results in the online questionnaire. The plots of positive identity, likability of robot and enjoyment of the game altogether show that participants evaluate section 3 which shows the robot with positive motion and voice traits as the most favorable and section 2 which shows the robot with negative motion and voice traits as the least favorable.

Meanwhile, section 4 which shows the robot with negative motion and normal voice traits and section 5 which shows the robot with positive motion and normal voice traits almost show no difference in each question. Similarly, in section 2 which shows the robot with negative motion and voice traits and section 6 which shows the robot with normal motion and negative voice traits evaluations are kind of close. On the other hand, there are quite apparent differences between the results in section 6 and section 7 in which the robot merely showed negative and positive voice.

The evidence aforesaid has shown that participants could figure out voice changes, enjoyed the game more and evaluated the robot with a positive voice more favorable. The distinguishing distinction of voice changes and similar evaluation of motion differences have presented that participants are more sensitive for robot's voice features but less sensitive towards robot motion.

However, individual differences have also shown. The results in section 3 which shows the robot with positive motion and voice traits and section 7 which shows the robot with normal motion and positive voice traits are perceived as the same in positive identity. Although the results of these two sections are assessed very similarly in likability and enjoyment, the plots have shown that compared to that of section 7, the results in section 3 distributes in a wider range which

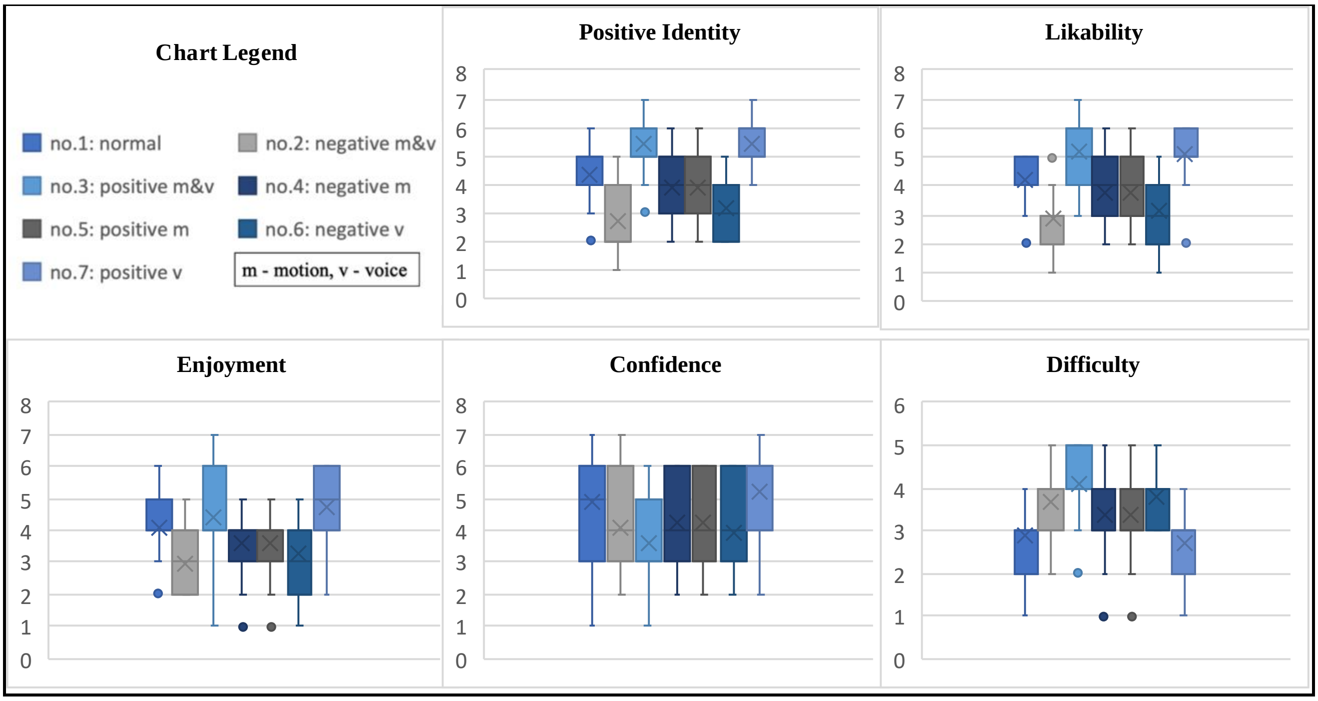

Fig. 3. Box and Whisker Chart of Questionnaire Results

have uncovered individual perception and preference differences towards the robot's expressions.

4.3. Relationship between Attitudes and Anxiety towards Robot and Questionnaire Results

According to the analysis of Pearson correlation between each answer in the questionnaire and each sub-scale in NARS and RAS, the positive identity and likability towards robot in section 2 which showed the robot with negative motion and voice traits have shown distinguishing negative correlation with RAS-S1 which measures the anxiety toward communication capacity of robots. The Pearson correlation values between the aforementioned traits in the questionnaire and RAS-S1 are equal to -0.698 and -0.785 respectively (both p-value < 0.05). Meanwhile, the results of either only voice or motion being negative hasn't shown any significant correlation with this aspect, exposing the fact that the participant who feels more anxious about robot communication ability is also more perceptive of the robot with negative motion and voice simultaneously and tends to evaluate it as unfavorable. However, no significant correlation between attitudes and anxiety towards robot and questionnaire results has been shown in other sections.

4.4. Discussion

As revealed in the relationship between the RAS-S1 score and evaluation of the robot with negative motion and voice expression, there is a statistical trend toward a significant effect of anxious attribution: the more the participants estimated the communication capacity of robot as being anxious, the lower scores of the likability they evaluated the robot. It is supposed that negative expression combining motion and voice has incurred the participant's anxiety strongly who shows more intensive anxiety towards the robot's communication capacity. Considering the results that no significant differences have been exhibited when robot merely expressed with negative voice or motion, the higher RAS-S1 score is not corresponding to be more sensitive to a single dimension of the negative features but the combination of them.

Besides, it has intrigued our attention that unlike the general division way of groups such as the gender and nation differences, except for a relationship between one's mother language and S1 sub-scale in Robot Anxiety Scale, the results of NARS and RAS scores have shown significant personal variation. In our previous studies, the individual traits including personality and perception have shown more distinguishing influence on one's interaction with a robot instead of gender and nation features [17], [25]. Therefore, the consideration of specific individual situation instead of the typical labels is indispensable. We are going to conduct the individual-based analysis on the attitudes and anxiety towards robots, attempting to find more latent relationship between personal traits and interaction patterns with the robot. In this way, it is promising to utilize the principles to facilitate adaptive human-robot interaction.

Finally, some limits need to be addressed in this study. Because the online experiments inevitably differ from the real human-robot interaction and limited participants from the same subject background have been selected in this experiment, it is not yet possible to conclude that the results are applicable to all situations and all kinds of people. On the other hand, the design and data process of questionnaires aiming to collect participants subjective evaluations need to be better handled to avoid response bias. Subsequent studies are expected to expand the representative sample and be explained by using machine learning.

5. CONCLUSION AND FUTURE WORK

In this paper, we have conducted an online questionnaire experiment presenting different robot expression styles to collect people's feedback, intending to explore the characteristics of human perception considering the aspect of attitudes towards robots. Results have shown that even though the robot behaved in different ways in the tasks, people are much less sensitive to the robot's motion traits than its voice features. Furthermore, for the targeted goal, attitudes towards robot have been integrated with the evaluation of robot expressions in which results show a relationship between the anxiety of the robot's communication capacity and perception of the robot when it behaves in negative motion and voice at the same time. Also, the discrepancy of the results of the attitudes implies that robotics design must take account of individual differences instead of only conforming with the average level as the criterion.

This study is expected to help researchers construct the valid robot expressions for different individuals in human-robot interaction which can motivate predictive responses based on users' perception and psychological traits.

We plan to conduct a follow-up study including more exploration of individual-based factors relating to one's perception of the robot by measuring human behaviors and feelings in human-robot-interaction, aiming to facilitate the natural social interaction without the distraction of trivialized and unnecessary actions.

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Appendix A.

A.1. Negative Attitudes Toward Robots Scale (NARS)

Subscale	Questionnaire Items
S1	I would feel uneasy if I was given a job where I had to use robots.
	The word "robot" means nothing to me.
	I would feel nervous operating a robot in front of other people.
	I would hate the idea that robots or artificial intelligences were making judgements about things.
	I would feel very nervous just standing in front of a robot.
	I would feel paranoid talking with a robot.
S2	I would feel uneasy if robots really had emotions.
	Something bad might happen if robots developed into living beings.
	I feel that if I depend on robots too much, something bad might happen.
	I am concerned that robots would be a bad influence on children.
	I feel that int the future society will be dominated by robots.
S3	I would feel relaxed talking with robots. ∗
	If robots had emotions I would be able to make friends with them. ∗
	I feel comforted being with robots that have emotions. ∗
(∗Reverse Item)	

A.2. Robot Anxiety Scale (RAS)

Subscale	Questionnaire Items
S1	Robots may talk about something irrelevant during conversation
	Anxiety toward Communication Capability of Robots Conversation with robots may be inflexible
	Robots may be unable to understand complex stories
S2	How robots will act
	Anxiety toward Behavioral Characteristics of Robots What robots will do
	What power robots will have
	What speed robots will move at
S3	How I should talk with robots
	Anxiety toward Discourse with Robots How I should reply to robots when they talk to me
	Whether robots understand the contents of my utterance to them
	I may be unable to understand the contents of robots' utterances to me