EXPERIMENTAL INVESTIGATION OF RELATIONSHIPS BETWEEN ANXIETY, NEGATIVE ATTITUDES, AND ALLOWABLE DISTANCE OF ROBOTS

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ABSTRACT
When people interact with robots in daily life, each individual has different attitude and emotion toward the robots, which cause different behavior toward them. Thus, we should empirically investigate influences of attitudes and emotions into human–robot interaction, in particular, those of negative attitudes and anxiety which may directly affect behaviors toward robots. For this aim, an experiment was conducted to investigate relationships between negative attitudes and anxiety toward, and allowable distance of a robot. The results revealed that negative attitudes and anxiety toward robots affected allowable distances between the subjects and the robot, and the subjects' anxiety toward robots changed before and after the experiment session, depending on the robot's behavioral characteristics such as its walking speed.

KEY WORDS
Robots, Anxiety, Attitudes, Distance, Psychological Experiment

1 Introduction

Robots have been recently expected to be applied to daily–life fields such as entertainment, education, welfare, psychiatry, and so on [1, 2]. On the other hand, there may be the differences between individuals of attitudes or emotions toward robots. In addition, it has not been sufficiently clarified how these differences may influence human–robot interaction in daily–life applications of robots. Thus, empirically investigating the influence of humans' attitudes or emotions into interaction with robots can contribute to design of robots to be applied to daily–life fields.

There are experimental studies on the psychological influence on human behaviors toward robots. Kanda et al. investigated the impression on humans of a humanoid robot based on a psychological interaction experiment that measured impressions with the Semantic Differential method [3]. Goetz et al. proposed a "matching hypothesis" to explore relationships between robot appearances and tasks and found that friendlier tasks matched friendlier appearances [4]. Kidd and Breazeal conducted experiments to compare appearances between artificial agents and robots and found that robots are more suitable than agents for tasks such as pointing at objects related to real spaces [5]. Walters et al. experimentally confirmed relations between human personality traits measured by questionnaires and behaviors toward robots such as allowable distances [6]. Mutlu et al. found affection of gender and task structures in human perceptions of a humanoid robot (Honda's ASIMO), through an interaction experiment with the robot based on games [7]. However, these studies ignored attitudes reflecting individual opinions or emotions evoked in real situations of human–robot interaction toward robots.

On the other hand, Nomura et al. experimentally investigated relations between human negative attitudes toward robots and communication avoidance behaviors [8]. The results suggest the possibility that negative attitudes toward robots affected human behaviors toward them. However, the results did not sufficiently clarify these relationships. Moreover, the study did not consider emotions to be evoked in actual situations of human–robot interaction, such as anxiety.

This paper focuses on both negative attitudes and anxiety toward robots as psychological factors, and allowable distances between humans and robots as a behavior index in human–robot interaction, used in the work of Walters et al. [6]. We designed and conducted an experiment to investigate the relationships between these psychological factors and behavior toward robots. This paper reports the results of the experiment and discusses their implications from the perspective of robotics design.

2 Experiment

2.1 About Prior Hypothesis in the Experiment

The experiment aimed at exploratory investigating relationships between humans' anxiety and negative attitudes, and behaviors toward robots. Then, we did not have any prior hypothesis.

In fact, although the experimental works of Walters et al. [6] and Mutlu et al. [7] had some prior hypotheses implied from theories of human–human interaction, their

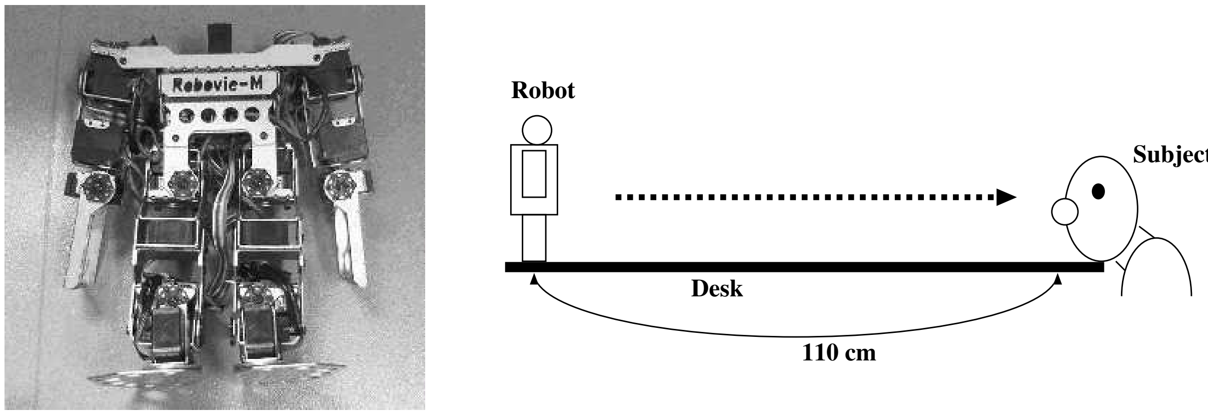

Figure 1. Robot and Experimental Situation

results did not sufficiently support them. This fact implies that theories of human–human interaction cannot necessarily be used in human–robot interaction since the latter may have a specific aspect different from the former. Our research aims at exploration of relationships between humans' psychological factors and behaviors toward robots that can be used for construction of prior hypotheses in future research of human–robot interaction.

2.2 Subjects and Robot Used in the Experiment

The experiment was conducted from August to October, 2006. 17 Japanese university students were recruited with 1,000 Yen for the experiment (males: 12, females: 5), whose mean age was 19.0.

In this experiment, a small–size humanoid robot "Robovie–M," which has been developed by Vstone Corporation, was used[1]. Figure 1 shows the robot. This robot stands 29 cm tall and weighs about 1.9 kg. The robot has 6 DOF at each foot, 4 DOF at each arm, 1 DOF at waist, 1 DOF at shoulder, a total of 22 DOF. This large number of DOF allows it to execute various gestures such as walking, bowing, and a handstand.

The behaviors of the robot can be controlled by the connected PC and the software tool for programming. In this experiment, the robot performed a simple walking behavior toward human subjects. To investigate the influence of the robot's behavioral characteristics into subject's anxiety toward robots, two kinds of walking speed (6.0 cm/sec and 12 cm/sec) were prepared.

2.3 Measures

As a behavior index of subjects toward the robot, allowable distances of the robot were measured in the experiment.

The experimental work of Walters et al. [6] adopted both human–robot and robot–human approach distances allowable for subjects, and investigated their relationships with personality traits. In this experiment, only robot–human approach distances were used as a behavior index.

As shown in Figure 1, subjects' allowable distances of the robots were measured as follows:

1. The subject put his/her head on the edge of the desk in the experiment room.
2. The robot stood at the front position with distance 110 cm of the subject.
3. Then, the robot approached walking toward the subject.
4. The subject ordered the experimenter to stop the robot's walking at the moment when he/she felt anxiety or fear toward the approach of the robot.

The above scenes in the experiment were videotaped. Then, the distance between the subject and position at which the robot stopped was measured from the video data. This measurement was performed with 5 cm per unit.

Next, as psychological factors of subjects, negative attitudes and anxiety toward robots were measured before the experiment.

In the research field of technophobia, computer anxiety and attitudes have been investigated as its factors [9]. In particular, computer anxiety has been studied from the perspective of educational psychology [10, 11]. In order to measure these factors in our human–robot interaction experiment, we adopted two psychological scales, Negative Attitudes toward Robots Scale (NARS) [8] and Robot Anxiety Scale (RAS) [12]. Table 1 shows the questionnaire items and subscales of these scales[2].

NARS measures humans' attitudes toward robots, that is, psychological states such that opinions individuals usually have about robots. This scale consists of fourteen questionnaire items. These items are classified into three subscales, NARS-S1: "Negative Attitude toward Situations of

[1] see `http://www.vstone.co.jp/e/rt01e.htm`

[2] Nomura et al. [8, 12] notes that the English sentences of items in the NARS were made through formal back–translation, although those in the RAS have been not.

Table 1. Questionnaire Items of Negative Attitudes toward Robots Scale and Robot Anxiety Scale, and Names of their Subscales [8, 12]

Negative Attitudes toward Robots Scale (NARS)

Subscale	Item
S1: Negative Attitude toward Situations of Interaction with Robots	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 judgments about things. I would feel very nervous just standing in front of a robot. I would feel paranoid talking with a robot.
S2: Negative Attitude toward Social Influence of Robots	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 in the future society will be dominated by robots.
S3: Negative Attitude toward Emotions in Interaction with Robots	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)

Robot Anxiety Scale (RAS)

Subscale	Item
S1: Anxiety toward Communication Capability of Robots	Robots may talk about something irrelevant during conversation Conversation with robots may be inflexible Robots may be unable to understand complex stories
S2: Anxiety toward Behavioral Characteristics of Robots	How robots will act What robots will do What power robots will have What speed robots will move at
S3: Anxiety toward Discourse with Robots	How I should talk 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

Interaction with Robots" (six items), NARS-S2: "Negative Attitude toward Social Influence of Robots" (five items), and NARS-S3: "Negative Attitude toward Emotions in Interaction with Robots" (three items).

Each item of NARS has a score on five–point scale (1: I strongly disagree, 2: I disagree, 3: Undecided, 4: I agree, 5: I strongly agree), and an individual's score on each subscale is calculated by summing the scores of all the items included in the subscale, with the reverse of scores in some items. Thus, the minimum and maximum scores are 6 and 30 in NARS-S1, 5 and 25 in NARS-S2, and 3 and 15 in NARS-S3, respectively.

RAS measures humans' anxiety toward robots to be evoked in real and imaginary situations of human–robot interaction. In contrast with the NARS, this scale aims at measuring state–like anxiety that may be evoked by robots. This scale consists of eleven questionnaire items. These items are classified into three subscales, RAS-S1: "Anxiety toward Communication Capacity of Robots" (three items), RAS-S2: "Anxiety toward Behavioral Characteristics of Robots" (four items), and RAS-S3: "Anxiety toward Discourse with Robots" (four items).

Each item of RAS has a score on six–point scale (1: I do not feel anxiety at all, 2: I hardly feel any anxiety, 3: I do not feel much anxiety, 4: I feel a little anxiety, 5: I feel much anxiety, 6: I feel anxiety very strongly), and an individual's score on each subscale is calculated by summing the scores of all the items included in the subscale. Thus, the minimum and maximum scores are 3 and 18 in RAS-S1, 4 and 24 in RAS-S2, and 4 and 24 in RAS-S3, respectively.

Finally, as another psychological factor, state anxiety was measured before the experiment.

The emotion of anxiety is generally classified into two categories: state and trait anxiety. Trait anxiety is a trend of anxiety as a characteristic stable in individuals whereas state anxiety is an anxiety transiently evoked in specific situations and changed depending on the situation and time [13]. It was revealed that computer anxiety is a kind of state anxiety [10]. On the other hand, robot anxiety has low level

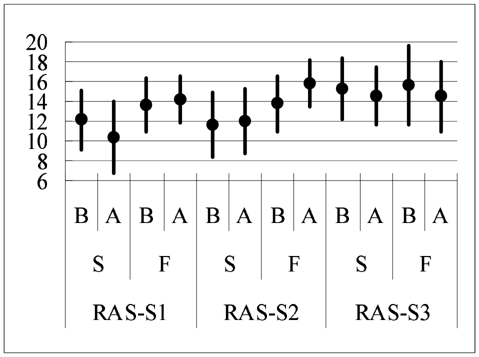

Figure 2. Means and Standard Deviations of RAS Subscale Scores Before and After the Experiment Session (S: group of the subjects who experienced with the slower robot ($N = 9$), F: group of the subjects who experienced with the faster robot ($N = 8$), B: before the experiment session, A: after the experiment session)

of correlations with state anxiety [12], although negative attitudes toward interaction with robots have a moderate level of correlation with state and trait anxiety [14].

In the experiment, State–Trait Anxiety Inventory (STAI) [13] was used to investigate whether anxiety toward robots is evoked by real human–robot interaction situations. STAI consists of twenty items for measuring state anxiety (STAI–S) and twenty items for measuring trait anxiety (STAI–T). In the experiment, only STAI–S was used to measure the subjects' general anxiety before the experiment and analyze its relations to negative attitudes and anxiety toward robots.

2.4 Procedures

One session of the experiment was conducted based on the following procedures:

1. After the experimenters explained the aim of the experiment, the subject responded to the following questionnaire items: 1: sex, 2: age, 3: the NARS, 4: the RAS, 5: STAI–S.
2. The experimenters lead the subject to the experiment room. Then, the experimenters introduced the robot to the subject and explained the instruction in the experiment.
3. The subject's allowable distance of the robot was measured in the way shown in section 2.3.
4. Finally, the subject responded to the questionnaire items of the RAS, again.

Each subject experienced with one session. In each session, the walking speed of the robot was randomly determined at either slower (6 cm/sec) or faster one (12 cm/sec). The RAS was administered both before and after the session to confirm the change of subject anxiety toward robots.

Table 2. Results of Mixed ANOVAs with Speed condition of the Robot and Condition before/after the Experiment Session for RAS Subscale Scores ($df_1 = 1$, $df_2 = 15$)

Subscale		Slower/ Faster	Before/After Session	Interaction
RAS-S1	F	3.967	.863	4.177
	p	.065	.368	.059
RAS-S2	F	4.619	5.963	3.043
	p	.048	.027	.102
RAS-S3	F	0.015	1.091	.071
	p	.903	.313	.793

Table 3. Regression Model for Allowable Distance ($N = 16$, $p = .066$)

Independent Variable	β	t	p
RAS-S1	.677	2.569	.025
RAS-S2	.497	1.776	.101
NARS-S2	-.596	-1.846	.090
R^2	.298		

3 Results

Figure 2 shows the means and standard deviations of the subjects' RAS subscale scores before and after the experiment sessions. Moreover, table 2 shows the results of two–way mixed ANOVAs with the speed condition of the robot and condition before/after the session for these scores.

These results revealed the statistically significant main effects of both the speed condition of the robot and condition before/after the session in the score of RAS-S2. Moreover, they revealed the statistically significant trend of interaction effect in the score of RAS-S1.

Next, linear regression analysis was conducted to investigate the relations between the subjects' anxiety and negative attitudes toward robots measured just before the experiment sessions, and allowable distances of the robot. The regression analysis was performed based on backward elimination method.

Although no statistically significant regression model was extracted, the model shown in table 3 had a statistically significant trend, suggesting that the allowable distances of the robot was influenced by the scores of RAS-S1 and NARS-S2.

Finally, Pearson's coefficients r between the NARS and RAS scores and STAI-S were calculated to investigate the relations between the negative attitudes and anxiety toward robots as well as the general anxiety of the subjects just before the experiment.

Table 4 shows these correlation coefficients. There was a high level of correlation between NARS-S1 and STAI-S. Moreover, there were moderate levels of correla-

Table 4. Pearson's Correlation Coefficients r between RAS and NARS Subscales and STAI ($N = 17$)

		RAS-S1	RAS-S2	RAS-S3	NARS-S1	NARS-S2	NARS-S3
RAS-S2	r	.329					
	p	.197					
RAS-S3	r	.238	.511				
	p	.358	.036				
NARS-S1	r	.075	.511	.195			
	p	.776	.036	.452			
NARS-S2	r	.497	.437	.139	.336		
	p	.042	.080	.594	.187		
NARS-S3	r	.460	.280	-.034	.375	.364	
	p	.063	.276	.897	.138	.150	
STAI	r	-.238	.360	.003	.759	-.001	-.104
	p	.358	.155	.990	.000	.996	.691

tions between RAS-S2 and RAS-S3, RAS-S2 and NARS-S1, and RAS-S1 and NARS–S2.

4 Discussion

The results of the mixed ANOVAs for the RAS scores show that subject anxiety toward behavioral characteristics of robots increased after the experiment session. Moreover, they suggest that the robot's approaching speed affect the change of subject anxiety toward behavioral characteristics of robots and communication capacity of robots. Although there may be dependence on types of robots, this implies that experiences with robots can change human anxiety toward them.

On the other hand, the result of regression analysis implies that anxiety and negative attitudes toward robots before experiences with robots can influence behaviors toward them such as allowable distances of robots. This suggests that repeated experiences with robots can change human behaviors toward robots, depending on robots' behavioral characteristics.

From the above implications, we obtained some suggestions for robot design to be applied to daily–life fields.

The RAS revealed the increase of anxiety toward behavioral characteristics of robots after the experiment sessions. We believe that the increase of anxiety was caused by direct approach of the robot in the specific situation of the experiment. In other words, the ways of humans' experiences with robots can affect psychological factors related to robots and these factors can affect behaviors toward robots.

By measuring humans' psychological factors specific on robots such as attitudes and anxiety toward robots, we may be able to explore which type of robot design raises or reduces these psychological factors and which type of behavior is encouraged by a specific design of robots. Such exploration is important when long–term interaction between robots and users is assumed, since repeated experiences may increase or decrease emotions toward robots and, as a result, specific behaviors.

In fact, it has still not sufficiently clarified what psychological mechanisms can affect human–robot interaction. For example, our experimental results imply that negative attitudes toward the social influence of robots may negatively affect, that is, paradoxically in contrast with anxiety toward communication capacity of robots. Thus, experimental studies focusing on humans' psychological factors related to robots, as shown in the paper, are considered to be important for evaluating the usability of robots in daily life.

Finally, we should note that the results in the paper have some limitations.

The subjects were limited to Japanese university students. Thus, the implications outlined in the previous section do not consider differences of age or cultural background on anxiety and attitudes toward robots and their connection with behaviors. Moreover, there is also a limitation of the implications due to the small number of samples in the experiment.

The above problems must be solved in future experiments by improving experimental design, for example, sampling from a wider area of ages and cultures, using several types of robots, and so on.

5 Summary

This paper reported the results of the experiment conducted to investigate relationships between negative attitudes and anxiety toward, and allowable distance of a robot. The results revealed that negative attitudes and anxiety toward robots affected allowable distances between the subjects and the robot, and the subjects' anxiety toward robots changed before and after the experiment session, depending on the robot's walking speed.

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