Measurement of Anxiety toward Robots

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Abstract— **To study the short–term and long–term influence of communication robots in daily life applications, it is necessary to develop psychological scales for measuring the mental states of users of robots and analyzing related social trends. In particular, to explore the more internal factors related to communication robots, it is necessary to focus on anxiety. This paper reports the results of developing the Robot Anxiety Scale (RAS) for measuring the anxiety that prevents individuals from interaction with robots having functions of communication in daily life. In particular, we focus on communication in a human-robot dyad.**

I. Introduction

A great deal of study has been performed recently on robots that feature functions for communicating with humans i.e., communication robots. This research has many applications such as entertainment, education, and psychiatry [1], [2]. Then, we should consider how successful human–likeness of robots psychologically affect interaction with humans in these applications. In other words, it is necessary to clarify what type of psychological reaction robots like humans or those unlike humans can evoke in humans. For the aim, it is necesary to develop measurement methods of human mental states in interaction with robots. These measurement methods can contribute not only to directly evaluating the design of robots but also to clarifying psychological factors in evaluating success of human–like robots.

In the research on human factors in communication with robots, some studies have focused on what attitudes or emotions humans actually have toward communication robots [3], [4], [5], [6]. These studies were aimed at exploring human evaluations of specific robots. On the other hand, some studies have more strongly focused on humans to explore what behaviors and subjective evaluations different robots evoke in humans [7], [8], [9]. The authors of these studies have their own perspectives on how robots should be designed and in what situations these robots can be used. Furthermore, other studies have examined the acceptance of robots at the social level [10], [11], [12], [13], [14]. These studies focused on the social relationships between humans and robots.

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The studies mentioned above, however, dealt simply with the measurement of people's subjective impression or behaviors toward robots in specific situations; they do not straightforwardly take into account concrete emotions or attitudes that humans may have toward robots, or the differences in these factors. Although there is an experimental study dealing with relations between personal traits measured by a questionnaire and behaviors toward robots [15], it does not measure emotions toward robots themselves. We have been focusing on the psychological factors that can evoke people's negative reactions toward communication robots and trying to develop psychological scales that can measure these factors [16], [17], [18]. In this paper, we focus on anxiety toward robots and show the results obtained through the development of a scale to measure this anxiety.

II. Definition and Hypothesis

Negative emotions such as anxiety should be given more attention in human–robot interaction. First, some research has found that humans tend to have either extremely positive or extremely negative attitudes toward novel communication technologies [19]. If communication robots can be regarded as a novel communication technology, there is the possibility that humans will have negative attitudes or emotions toward these robots. Second, technophobia including computer anxiety [20] has been studied and found to be widespread with information technology [21]. Thus, it is important to study possibility of a specific type of technophobia in human–robot interaction.

This section presents psychological concepts related to anxiety toward robots, the definition of robot anxiety, and its hypothetical model.

A. Anxiety and Robot Anxiety

Anxiety is psychologically defined as a feeling of mingled dread and apprehension about the future without a specific cause for the fear, a chronic fear of a mild degree, strong overwhelming fear, a secondary drive involving an acquired avoidance response, or the inability to predict the future or to resolve problems [22].

Regarding computers, which are similar to communication robots in the sense that they are strongly associated with information technology products and interaction with users, computer anxiety has been studied from the perspective of educational psychology [20], [23]. On the analogy of computer anxiety in learning situations, it is necessary to explore anxiety toward communication robots when these robots are introduced in daily life. Thus, it is important to prepare methods to measure human anxiety that may prevent them from interacting with communication robots. These psychological methods are assumed to provide important indices for studying short–term and long–term interaction between humans and communication robots in the recent situation where the introduction of these robots to the home, welfare, and psychiatric fields may be encouraged.

Our previous research resulted in a psychological scale measuring negative attitudes toward robots, not anxiety itself [18]. Attitudes are 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 [22]. We found that negative attitudes may not have much influence on humans' concrete behaviors toward robots in real situations. To explore the more internal factors related to communication robots, we need to focus on anxiety.

B. *Definition of Robot Anxiety and Its Hypothetical Model*

We define robot anxiety as the emotions of anxiety or fear preventing individuals from interaction with robots having functions of communication in daily life, in particular, communication in a human-robot dyad. Fig. 1 graphically shows a hypothetical model of robot anxiety. We hypothesize that robot anxiety is mainly caused by two existing psychological factors. One of them is anxiety toward technological products including the computer anxiety mentioned above, and the other is communication apprehension [24], [25].

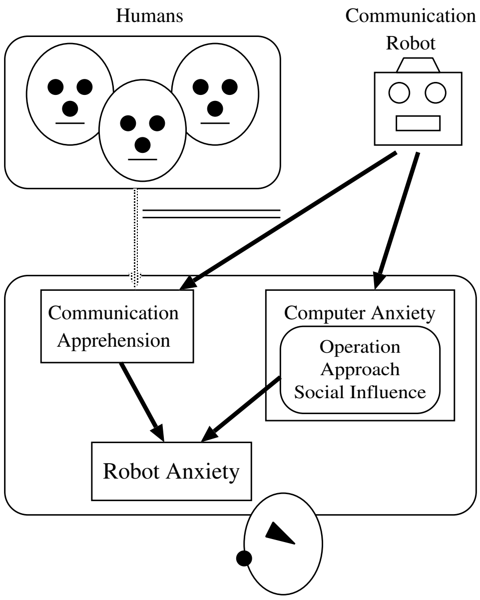

Fig. 1. Hypothetical Model of Robot Anxiety

Communication apprehension (CA) is one of the concepts in communication avoidance research regarding the difference between individuals with respect to fear and avoidance of social communication, or preference of attendance to and acceptance of social communication. CA is defined as an individual's level of fear or anxiety associated with either real or anticipated communication with another person or persons [25]. One important characteristic of CA is that it is a fear or attitude toward communication itself: CA is a type of social anxiety. In general, social anxiety is caused by facing negative evaluations from others and predicting this experience in real or imaginary social situations. However, CA is mediated by emotional reactions learned through repetition of communication and negative stimuli, negative thinking, and skill deficit. In other words, CA is not directly caused by evaluations from others but by a kind of conditioned response toward communication.

This characteristic of CA provides an important suggestion: Since CA is caused as a conditioned response toward communication and humans tend not to discriminate between humans and machines in interaction [7], CA may occur even in communication between humans and robots. In other words, since CA is evoked by communication without cognition of evaluation from others — and humans do not discriminate between communication with humans and communication with artificial agents - humans with higher CA may evoke CA even in communication with robots. This may lead to anxiety toward robots.

III. Development of the Robot Anxiety Scale

Considering the definition and hypothesis presented in the previous section, this section presents the process of developing a Robot Anxiety Scale (RAS) and the results of analysis for test data.

A. *Pilot Survey*

To explore candidate items for a questionnaire, we administered a pilot survey by gathering opinions of anxiety toward robots from April 2004 to May 2004.

This survey was based on questionnaires in free writing form. The respondents were Japanese participants assembled for experiments on human–robot interaction for another aim [17]. After these experiments, the participants responded to the following questions by freely giving answers:

1) "Did you feel anxiety when you faced the robots in the experiments? If so, please answer freely and concretely on how you felt anxiety."
2) "If you faced robots in daily life, such as in houses, offices, and schools, in what situations would you feel anxiety? Moreover, what type of anxiety would you feel concretely? Please answer freely."

From the data collected from the 48 respondents, we selected sentences related to anxiety and situations where it is likely to be evoked. After modifying the expression of these sentences, we selected several sentences. The content validity of these items was discussed among two engineering researchers and two psychologists.

B. *Item Selection and Verification of Internal Consistency and Factorial Validity*

To select appropriate items from the items extracted in the pilot survey and verify the internal consistency and factorial validity, a pre–test was executed in the following way:

TABLE I

QUESTIONNAIRE ITEMS OF ROBOT ANXIETY SCALE, NAMES OF SUBSCALES, AND COEFFICIENTS BETWEEN ITEMS AND THE CORRESPONDING SUBSCALES IN CONFIRMATORY FACTOR ANALYSIS

Subscale	Item	Path Coefficients
S1	Robots may talk about something irrelevant during conversation	0.879
Anxiety toward Communication Capability of Robots	Conversation with robots may be inflexible	0.863
	Robots may be unable to understand complex stories	0.860
S2	How robots will act	0.700
Anxiety toward Behavioral Characteristics of Robots	What robots will do	0.755
	What power robots will have	0.836
	What speed robots will move at	0.677
S3	How I should talk with robots	0.759
Anxiety toward Discourse with Robots	How I should reply to robots when they talk to me	0.649
	Whether robots understand the contents of my utterance to them	0.649
	I may be unable to understand the contents of robots' utterances to me	0.620

1) Method: In developing this scale, we assigned each questionnaire item 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). Note that the following procedures were executed in Japan, and thus all of the respondents were Japanese.

The participants were drawn from universities. The prototype version of RAS, consisting of the questionnaire items extracted in the pilot survey, was administered from April 2005 to June 2005, during lecture time. Participation of the respondents was voluntary. A total of 241 people (male: 151; female: 87; unknown: 3; mean age: 19.6) participated.

2) Results: First, an exploratory factor analysis of the data was conducted using the maximum–likelihood method with Promax rotation. A three–factor structure was chosen based on the scree plot and item consistency. Three subscales consisting of 11 items (first factor: 3 items, second factor: 4 items, third factor: 4 items) were extracted based on factor loadings, the contents of the items, and the results of item analysis in each subscale, which consisted of I–T correlation coefficients and α–coefficients.

Then, a confirmatory factor analysis using structure equation modeling was conducted for this model. The goodness–of–fit indices of the model were $GFI = 0.911$, $AGFI = 0.857$, and $RMSEA = 0.094$. Since the first subscale (S1) consisted of the items related to consistency, flexibility, and comprehension capability of communication with robots, it was named "anxiety toward communication capability of robots." Since the second subscale (S2) consisted of the items related to actions and behavioral characteristics of robots, it was named "anxiety toward behavioral characteristics of robots." The third subscale (S3) consisted of the items related to discourse with robots and the flow of such discourse. Thus, it was named "anxiety toward discourse with robots." The α–coefficient of the first subscale was 0.900, that of the second subscale was 0.828, and that of the third subscale was 0.800.

Table I shows the items of RAS, the names of the subscales, and the path coefficients between the items and the corresponding factors in the confirmatory factor analysis. Note that the English sentences in Table I are naively translated from the original Japanese sentences, not translated according to formal procedures including back translation.

The degree of robot anxiety measured by each subscale is calculated by summing the scores of the items that the subscale includes. Thus, the minimum and maximum scores of these subscales are as follows: S1: $min : 3$, $max : 18$, S2: $min : 4$, $max : 24$, S3: $min : 4$, $max : 24$.

IV. ANALYSIS OF OTHER TEST DATA

To confirm the cross validity and construct validity of RAS, another test has been conducted from November 2005 to March 2006.

A. Method

Just as in the pre–test, the participants were Japanese university students. The version of RAS confirmed in the pre–test was administerd during lecture time. Participation of the respondents was voluntary.

In the test, two psychological scales were administerd to confirm the construct validity of the RAS. One is the State–Trait Anxiety Inventory (STAI) for measuring general anxiety [26]. Emotions of anxiety are generally classified into two categories: state and trait anxiety. Trait anxiety is a trend of anxiety as a characteristic stable in individuals while state anxiety is an anxiety transiently evoked in specific situations and is changed dependent on situations and time. STAI consists of twenty items for measuring state anxiety (STAI–S) and twenty items for measurfing trait anxiety (STAI–T). Another is the Personal Report of Communication Apprehension (PRCA–24) [25]. PRCA–24 measures communication apprehension in four contexts: public speaking, meetings, small group discussion, and dyads. Each context corresponds to six items. In this administration, only six items corresponding to dyads were used.

Moreover, our previous research implied the possibility that individuals' assumptions about robots (their types, situations where they exist, and so on) may affect their attitudes and emotions toward robots [18], [27]. Thus, the face sheet in this administration included items that asked respondents to answer which type of robots they assumed and which tasks they assumed the selected robots do. The choices of the former item were human–size humanoids, small–size humanoids, big active robots, animal–type robots, stationary

TABLE II

PEASON'S CORRELATION COEFFICIENTS r BETWEEN RAS SUBSCALES, STAI, AND PRCA–24

	S2	S3	STAI–S	STAI–T	PRCA–24
S1 Male r	0.212**	0.495***	-0.005	0.093	0.096
N	172	172	159	158	149
S1 Female r	0.175*	0.607***	0.168*	0.148	0.250**
N	177	177	171	173	166
S2 Male r		0.303***	0.066	0.061	0.146
N		172	159	158	149
S2 Female r		0.288***	0.063	0.183*	0.068
N		177	171	173	166
S3 Male r			0.090	0.202*	0.180*
N			159	158	149
S3 Female r			0.110	0.192*	0.184*
N			171	173	166

(*$p < .05$, **$p < .01$, ***$p < .001$)

machines, arm–manipulators, and others. The choices of the latter item were: housework, office work, public service such as education, medical or welfare service, construction or assembling tasks, guard or battle, tasks in places hard for humans to go or hazardous locations such as the space and the deep sea, the service trade, communication partners or playmates, amusement, and others. These choices were determined based on the previous pilot study [27].

As a result, a total of 400 people (male: 197; female: 199; unknown: 4; mean age: 21.4) have participated.

B. Results

1) Internal Consistency, Cross Validity, and Construct Validity: First, a confirmatory factor analysis using structure equation modeling was conducted for the model just as in the pre–test. The goodness–of–fit indices of the model were $GFI = 0.949$, $AGFI = 0.917$, and $RMSEA = 0.066$. The α–coefficient of the first subscale (S1) was 0.840, that of the second subscale (S2) was 0.844, and that of the third subscale (S3) was 0.796.

Then, to investigate relations between anxiety toward robots, general anxiety, and communication apprehension, Peason's correlation coefficients r between the RAS subscales, STAI, and PRCA–24 were calculated. Since there is a possibility of gender difference on anxiety and communication apprehension, this calculation was performed for each gender subgroup (in the test of this paper, it was confirmed that the female respondents had higher trait anxiety than the male respondents, male $N = 179$, female $N = 191$, $t = -4.159$, $p < .001$).

Table II shows these coefficients. The table reveals that there was a moderate level of correlation between S1 and S3, both of which are the subscales related to communication with robots. Moreover, it was revealed that there was a low level of correlation between S1, STAI–S (state anxiety), and PRCA–24 in the female respondents, although there was no correlation in the male respondents. Furthermore, it was revealed that there was a low level of correlation between S2 and STAI–T (trait anxiety) in only the female respondents. In addition, it was revealed that there was a low level of correlation between S3, STAI–T, and PRCA–24 in both the male and female respondents.

2) Relations between Anxiety toward and Assumptions about Robots: Next, we analyzed relations between the RAS scores and assumptions about robots measured in the face sheet.

First, it was calculated how many respondents selected each type and task of robot in the assumptions about robots. Then, to find relations between specific assumptions about types and tasks, ϕ–coefficients were calculated to show the extent of relationships between the assumption choices. In addition, we performed statistical tests of Fisher's method on selection for pairs of choices to investigate the statistical significance of these ϕ–coefficients based on independence among these choices.[1]

Table III shows the number of respondents who selected each robot type and task, and correlations between robot types and tasks. Regarding assumptions about robot type, about 50% of respondents selected "human–size humanoids." The humanoid type, including small–size ones, was selected by about 70% of respondents, while the selection rate of "animal–type robots" was about 7%. The respondents who selected "others" tended to mention concrete names of some robots appearing in media, such as "Doraemon" and "Asimo," in their sentences for answering. Regarding assumptions about robot task, there was no bias of respondents to a specific task; the respondents who selected "others" tended not to mention concrete tasks in their writtten answers.

Regarding relations between robot type and task, there was a moderate level of positive correlation between "big active robots" and "guard or battle" ($\phi = 0.340$, $p < .001$), between "animal–type robots" and "communication partners or playmates" ($\phi = 0.367$, $p < .001$), between "arm manipulators" and "construction or assembling tasks" ($\phi = 0.319$, $p < .001$), and between "others" and "others" ($\phi = 0.298$, $p < .001$).

TABLE IV

MEANS AND STANDARD DEVIATIONS OF THE SCORES OF RAS SUBSCALSE BASED ON GENDER AND ROBOT TYPE SUBGROUPS (OTHERS: TYPE SM+AM+OT)

			S1		S2		S3	
		N	Mean	SD	Mean	SD	Mean	SD
HH	Male	85	10.4	3.5	13.4	4.6	12.6	3.7
	Female	84	10.4	3.2	13.4	3.5	13.4	3.8
SH	Male	26	10.6	4.2	12.4	4.4	11.0	4.4
	Female	46	9.9	3.7	12.5	4.0	12.7	4.7
BA	Male	35	9.4	3.9	13.9	4.5	11.3	4.1
	Female	21	9.1	3.9	14.4	3.5	13.1	4.3
AT	Male	13	9.8	3.4	13.4	5.1	11.9	4.1
	Female	11	10.3	2.3	12.9	2.8	13.7	3.8
Others	Male	13	9.8	5.2	9.9	5.4	11.2	6.2
	Female	14	9.4	3.3	14.0	3.3	11.0	2.8

[1]For example, to investigate a correlation between "small–size humanoids" and "amusement," one 2 × 2 cross table consisting of selection/no–selection of "small-size humanoids" and "amusement" was made, and then the ϕ–coefficient was calculated and a test was done for this cross table.

TABLE III

THE NUMBER OF RESPONDENTS WHO SELECTED EACH ROBOT TYPE AND TASK

	Robot Task											
Robot Type	HW	OW	PS	MS	CT	GB	HL	ST	CP	AS	OT	Total
HH	53	8	0	5	9	19	26	11	30	31	4	196
SH	12	1	1	3	0	2	9	1	21	20	3	73
BA	1	2	1	0	5	23	13	0	5	10	1	61
AT	0	0	0	1	0	2	1	0	21	1	1	27
SM	0	1	1	0	2	0	1	0	0	0	0	5
AM	0	0	0	0	4	1	1	0	0	1	0	7
OT	2	0	0	1	0	0	1	0	9	3	6	22
Total	68	12	3	10	20	47	52	12	86	66	15	391

Robot Type: HH: human–size humanoids, SH: small–size humanoids, BA: big active robots, AT: animal–type robots, SM: stationary machines, AM: arm–manipulators, OT: others

Robot Task: HW: housework, OW: office work, PS: public service such as education, MS: medical or welfare service, CT: construction or assembling tasks, GB: guard or battle, HL: tasks in places hard for humans to go or hazardous locations such as the space and the deep sea, ST: the service trade, CP: communication partners or playmates, AS: amusement, OT: others

TABLE V

MEANS AND STANDARD DEVIATIONS OF THE SCORES OF RAS SUBSCALSE BASED ON GENDER AND ROBOT TASK SUBGROUPS (OTHERS: TASK OW+PS+MS+ST+OT)

			S1		S2		S3	
		N	Mean	SD	Mean	SD	Mean	SD
HW	Male	27	9.9	3.2	12.7	4.7	12.3	3.7
	Female	30	9.5	3.0	14.1	3.3	13.1	4.0
CT	Male	11	8.9	3.1	13.4	5.8	12.1	3.0
	Female	5	10.8	4.1	12.4	1.9	14.6	6.1
GB	Male	28	9.1	3.2	13.4	4.3	11.7	3.9
	Female	13	8.8	3.7	14.2	3.7	12.3	4.2
HL	Male	25	9.5	4.2	13.6	4.4	11.5	3.9
	Female	20	11.5	3.8	13.6	4.1	13.5	4.1
CP	Male	23	10.1	3.7	13.7	4.9	12.1	5.1
	Female	53	10.7	3.0	13.0	3.4	13.5	4.1
AS	Male	26	10.2	4.0	13.7	4.4	12.4	4.7
	Female	36	9.2	3.4	12.4	4.2	12.2	3.9
Others	Male	28	12.0	4.2	12.2	4.8	11.8	4.5
	Female	17	9.6	3.7	13.9	3.1	12.2	4.1

Second, to investigate relations between anxiety toward and assumptions about robots, two–way ANOVAs were executed with independent variables of gender and robot type, and variables of gender and robot task, respectively[2]. On this analysis, the subgroups of respondents who selected "stationary machines," "arm manipulators," and "others" were integrated into one subgroup according to their small number of respondents and correlations with robot task. Moreover, the subgroups of respondents who selected "office work," "public service such as education," "medical or welfare service," "the service trade," and "others" were integrated into one subgroup, according to their small numbers of respondents, correlations with robot type, and similarity in their content.

Table IV and table V show the means and standard deviations of the scores of RAS subscales based on gender and robot type subgroups, and based on gender and robot task subgroups, respectively. Moreover, table VI shows the F–values in the two ANOVAs for the scores of the RAS subscales. The results of these ANOVAs revealed that there were no statistically significant effect of gender, robot type, robot task, or interaction in the scores of the RAS subscales S1 and S2. There was only a statistically significant effect of gender in the scores of S3.

[2]No ANOVA with robot type and task were done due to existence of cells in which the numbers of respondents were zero.

TABLE VI

F–VALUES IN THE TWO ANOVAS FOR THE SCORES OF RAS SUBSCALES

	Gender	Robot Type	Interaction
S1	0.093	1.150	0.184
S2	2.109	1.896	1.526
S3	4.311*	1.862	0.437
	Gender	Robot Task	Interaction
S1	0.015	1.358	1.797†
S2	0.060	0.224	0.974
S3	4.213*	0.386	0.462

($^{\dagger}p < .1$, $^{*}p < .05$)

V. SUMMARY AND DISCUSSION

In this paper, we reported the results of developing the Robot Anxiety Scale (RAS) to measure the anxiety that prevents individuals from interaction with robots having functions of communication in daily life, particularly communication in a human-robot dyad. We confirmed the internal consistency and cross validity of the RAS for the test data. Moreover, we analyzed the relationships of this anxiety with assumptions about robots.

The above results have some implications and problems. First, the values of goodness–of–fit indices and Cronbach's α–coefficients showed the internal consistency and cross validity of the RAS in the test data. On the other hand, the factor structure of the RAS did not reflect two kinds of anxiety hypothesized, computer anxiety and communicatoin apprehension. Moreover, the correlations between the RAS, STAI, and PRCA–24 were low. Thus, we should reconsider the theoretical hypothesis of robot anxiety to confirm the construct validity, while exploring the existing research of technophobia [21].

Second, the gender difference on correlations between the RAS, STAI, and PRCA–24 implies the possibility of gender difference on mental relations between personal traits, evoked emotions, and behaviors toward robots in human–robot communication. However, we should be careful at this stage. To investigate gender difference on mental mechanisms toward robots, we should firstly explore psychological processes behind difference on anxiety itself, and relationships with behaviors. In addition, we need sufficient psychological backgrounds on gender difference about communication apprehension, its relations to communcation avoidance behaviors, and mental images about and attitudes to technological products.

Third, there was no diference on the RAS subscale scores between assumptions about robots. This fact implies the possibility that the RAS measures anxiety toward robots independent of the types of robots and their tasks. In the administration in this paper, however, all the respondents were Japanese. Moreover, the categories of robot type and task were not provided with in sufficiently strict ways, and experiences of respondents with robots were not measured. Thus, we should conduct more strict research to investigate relationships between anxiety toward and assumptions about robots, including cultural differences of technophobia [28]. For this aim, we are conducting a cross–cultural research on assumptions about robots themselves, while taking into account robot type and experiences with robots.

Finally, the most important is the predictive validity of the RAS and its confirmation based on psychological experiments of human–robot interaction. We are planning to conduct human–robot interaction experiments in the following way [18]: first, measure participants' robot anxiety using the RAS; then, measure behavior indices in interaction with a robot. We assume several behavior indices related to communication avoidance behaviors, such as distances between participants and the robot and participants' reaction time for utterance stimuli from the robots, in our investigation of the relationships between anxiety and behaviors toward robots.

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