The 2010 IEEE/RSJ International Conference on
Intelligent Robots and Systems
October 18-22, 2010, Taipei, Taiwan

Development of a Scale of Perception to Humanoid Robots: PERNOD

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Abstract— **In this study we explored basic dimensions used to perceive humanoid robots and developed a scale to evaluate perception of humanoid robots, PERNOD. Previous studies of perception of humanoid robots used psychological scales created for interpersonal perception between humans. This study clarified the basic dimensions of perception of humanoid robots and developed PERNOD by means of psychological methodology. The results revealed six basic dimensions of perception of humanoid robots: *Utility*, *Clumsiness of motion*, *Possibility of communication*, *Controllability*, *Vulnerability*, and *Objective hardness*. The 6 dimensions of PERNOD were originally developed for humanoid robots. Thus, these dimensions represent the organization of knowledge used in the recognition of humanoid robots. Usability of PERNOD was discussed.**

I. Introduction

RAPID and continuing enhancement of technologies for humanoid robots has important implications for research in both engineering and psychology. An especially important feature of humanoid robots is the possibility of being a kind of partner that can coexist and cooperate with human beings. For humans and robots to work together efficiently, it is important to understand how humans react to robots. Several studies have tried to clarify the aspects of humanoid robots that are critical in forming humans' psychological impressions or reactions and to explore designs that promote smooth interaction between humans and humanoid robots.

For example, the different appearances of humanoid robots do not affect the participants' verbal behaviors but affects their non-verbal behaviors such as distance and delay of response. [1]. Verbal reactions of humanoid robots' voice like "touch me" or "let's play" bring good psychological impression [2]. Thus, not only appearance but also behavior of humanoid robots has been clarified in relation to psychological impression or reaction to humanoid robots. Furthermore, not only one-way reaction from human or humanoid robots to another but also interaction between human and humanoid robots has shown to be related to psychological impressions to humanoid robots. For example, when human directs a humanoid robot to take an object face to face with each other, timing of utterance with each other influences impression of communication [3]. People report emotions and cognitions in response to different types of robot behavior during interactions with robots [4]. The method to evaluate psychological impression to humanoid robots has also been focused. [1] showed 4 factors for human to evaluate humanoid robots using SD method. [5] developed the Robot Anxiety Scale (RAS) for measuring the anxiety that prevents individuals from interaction with robots having functions of communication in daily life..

As above, the relationships between human and humanoid robots have received highly attentions and been investigated from both psychological and engineering perspectives. Although many studies were already conducted, there is still an important problem to investigate this topic.

That is, most of these studies have adopted psychological scales that were originally developed to evaluate perceptions between humans. In previous psychological studies of people's perceptions of other human beings, three basic dimensions were found to be familiarity, social desirability, and activeness [6]-[8]. Although each study used different name of dimensions, the contents of dimensions are similar with each other very much. These 3 dimensions were found to be common across different cultures, and scales for interpersonal perception were developed based on these dimensions in form of a SD scale [8]. But it seems a highly serious matter that it has not yet been demonstrated that these basic dimensions of interpersonal perception also function as basic dimensions of perception of robots.

In addition, previous studies have also asked participants directly what the researchers wanted to know. For example, in order to measure the psychological concept of intentionality of robots, participants might be asked, "How well is the robot making its intentions clear to you?" However, such concepts or social constructs, unlike physical features such as height or weight, cannot be measured with clear and objective scales. When researchers deal with psychological concepts, it is important to define them logically and to clarify aspects of the concepts empirically. To ask directly about a concept before it is defined or clarified creates the risk that the question does not fully express the concept.

Thus, based on psychological studies of interpersonal

Manuscript received October 9, 2001. This work was supported in part by Global COE of Osaka University.

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perception, we may therefore define the concept of the basic dimensions of perception of humanoid robots as the relatively enduring system of categories used in the perception and construing of humanoid robots [6]. It is then necessary to discover empirically what kinds of dimensions are used to perceive humanoid robots. Previous studies haven't clarified correctly what dimensions work to recognize humanoid robots by means of a psychological approach, then, the investigation about this matter contributes further studies about human and humanoid robots more efficiently.

The purpose of the present study was to clarify the basic dimensions in the perception of humanoid robots and to develop a scale of perception of humanoid robots, which we call PERNOD (PERception of humaNOiD robots). Furthermore, we investigated whether or not the scale of interpersonal perception [8] could be appropriately applied to humanoid robots.

II. Collecting elements of basic dimensions in the perception of humanoid robots

To clarify the basic dimensions of perception of humanoid robots, a preliminary study was conducted to collect free descriptions which would be used as the basis of the items of PERNOD. In the preliminary study, we asked participants to watch a 4-min. movie of a humanoid robot to make sure they were acquainted with actual humanoid robots. We then asked participants to describe their impressions of humanoid robots using an open-ended questionnaire. These descriptions were categorized into several groups according to similarity of meaning, and wordings were adapted to construct items of the close-ended questionnaire PERNOD.

A. Method

A questionnaire was distributed to university students in a school of medicine during the final 15 minutes of a psychological class. The facilitator distributed the open-ended questionnaires and instructed the students to watch a movie of a humanoid robot and then describe their impressions. The facilitator explained that this movie showed only an example of one particular humanoid robot, but their impressions should be about humanoid robots in general, including other humanoid robots. Results from 157 students (age M = 18.80, SD = 0.81; 83 male, 70 female) were obtained.

The robot HRP-2 (see Fig. 1)[9] was used to make the movie to show participants. To obtain basic dimensions that are used generally to recognize humanoid robots across various situations, not in specific situations like just scenes of interaction with humans, we aimed to make this movie to include scenes that this robot can do as various as possible.

Scenes included the robot walking, bowing its head, putting its hand on the handle of a bag, grasping a bottle, giving a bottle to a human, pushing a wheelchair with a human sitting on it, and synchronizing with another small robot. The total length of the movie was 4 minutes and 28 seconds and the movie was silent.

After the movie, participants were asked to describe their impressions of generic humanoid robots using an open-ended questionnaire. The questionnaire included the following instruction: "Please describe any impressions of humanoid robots." Because we were collecting natural descriptions of humanoid robots, we did not provide any other spoken or written instructions.

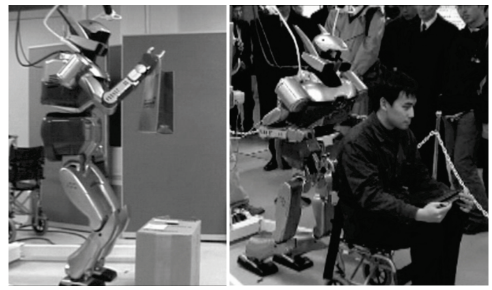

Fig. 1 Pictures of HRP-2 activities that were used in a stimulus movie. On the left one, HRP-2 is putting its hand on the handle of a bag and on the right it is pushing a wheelchair with a human sitting on it.

B. Results

Each participant described approximately 3 impressions, yielding a total of 454 descriptions. Each description was written on a card and 3 psychologists categorized the cards into several groups according to a similarity of the meanings. They identified what the person claimed to be important about impressions to the humanoid robot. This psychological meaning of the concepts was categorized for impressions. In other words, each card was categorized for the personal psychological meanings of impressions to the humanoid robot and not for the words that were used.

As a result of categorization, the following 10 groups were obtained (the numeral indicates the number of descriptions belonging to each category): *Admiration for technology of humanoid robots* (40), *Expectation of utility* (41), *Clumsiness of motion* (56), *Possibility of communication* (79), *Familiarity* (81), *Controllability* (35), *Anxiety about vulnerability* (37), *Objective hardness* (35), *Interest in price* (24), and *Other* (26). *Interest in price* and *Other* relatively included a few descriptions and contents to be able to shape sentences as items, then they were deleted.

Two psychologists considered the meanings of each description and reworded the descriptions into items of a close-ended questionnaire. The scales of SD method that was used in previous studies about evaluation to humanoid robots and also interpersonal perception are made in form of adjective of opposite meaning. But in this preliminary study we found that not the all descriptions coupled with each other in form of opposite meaning and were written in adjective. Each item was composed in a form suitable for a Likert scale response[10]-[12]. Each category included 4 to 6 items and the final scale was composed of 41 items.

C. Discussion

This study revealed impressions of the humanoid robot and provided data that would become items of PERNOD. In previous studies of perception of human beings, people were found to use basic dimensions of familiarity, social desirability, and activeness. The present results suggest that basic dimensions in the perception of humanoid robots are different from those of interpersonal perception.

These items were tested and further refined using factor analysis in the main study.

III. Refining of PERNOD by factor analysis

In this main study the conceptual structure of perception of humanoid robots was statistically investigated to confirm if factors that were found in the preliminary study differentiated from each other. By means of factor analysis the basic dimensions of perception of humanoid robots would be clarified. The relationships between these dimensions were also investigated.

Previous studies of perception of humanoid robots adopted the scale for interpersonal perception under the hypothesis that these perceptual dimensions were similar to those for perception of robots. It is necessary to confirm the similarity of perceptional dimensions by applying the scale for interpersonal perception to humanoid robots. Psychological studies have shown the basic dimensions of interpersonal perception to be familiarity, social desirability, and activeness, and these 3 factors were differentiated by factor analysis.

In the preliminary study, we collected people's impressions of generic humanoid robots for the purpose of exploration of basic perceptional items. In the main study, we asked people to evaluate a specific humanoid robot on the 2 scales, PERNOD and the interpersonal perception scale. If people evaluate impressions about generic humanoid robots on one scale at once, it is possible that people’s images about generic humanoid robots are different and the meaning of scores will be divergent relatively. Bur a specific humanoid robot would make evaluation more convergent than generic humanoid robots, it should reveal the factor structure of the scales more clearly.

A. Method

The procedure was almost the same as the preliminary study. A questionnaire was distributed to university students during the final 15 minutes of a seminar. The facilitator distributed the close-ended questionnaires and instructed participants to watch a movie of a humanoid robot and evaluate it on all items. The movie was the same as that used in the preliminary study. The facilitator also explained that the evaluation should be based on the humanoid robot in the movie.

The questionnaire was composed of 2 scales. One was PERNOD, constructed in the preliminary study, which consisted of 41 items using 7-point Likert scales from 1 (*strongly disagree*) to 7 (*strongly agree*). The second was the scale of interpersonal perception[8], with 20 items using 7-point SD scales..

A total of 380 university students who are different from the preliminary study (age $M = 20.31$, $SD = 2.89$; 140 males, 239 females, 1 unreported) completed the questionnaire.

B. Results and Discussion

An exploratory factor analysis with promax rotation was conducted on both scales. Exploratory rather than confirmatory factor analysis was used because no specific hypothesis about the structure or the number of dimensions underlying the set of variables for each scale was to be strictly confirmed.

Previous studies have shown that the factors of interpersonal perception are correlated with each other. We assume that perceptional dimensions reflect the way knowledge about objects is organized, or in other words, a cognitive. Therefore we adopted promax rotation to produce not orthogonal but correlated factors.

Analysis on the item level according to Kaiser's criterion (eigenvalues > 1.0) yielded 10 factors for PERNOD, and inspection of the screeplot showed less factors but over all interpretive significance revealed that a model containing six factors was more appropriate. As Fig. 2 shows, the screeplot flattened out considerably after the sixth factor. This result accounted for 54 % of the variance in the data. To form the final form of PERNOD, 33 items that loaded above .40 on each factor (and did not load above .30 on any other factor) were selected.

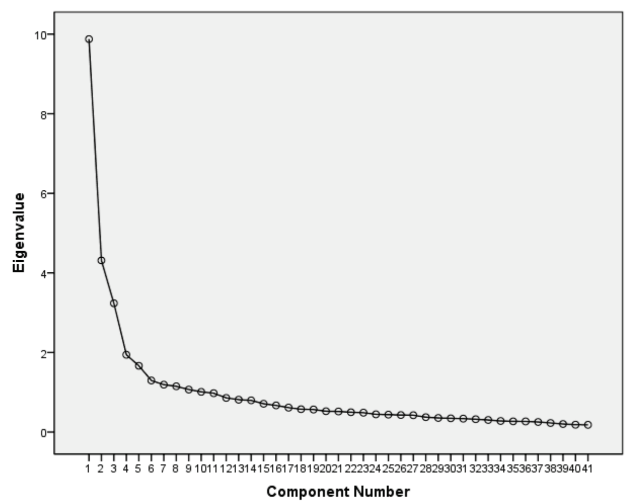

Fig. 2.A screeplot of the eigenvalues from the factor analysis. The screeplot suggests that six factors (subscales) can be extracted from the data.

Table 1 lists items and factor loadings of PERNOD and Table 2 provides interfactor correlations and reliability of each subscale. The first factor captured admiration of robot technology and expectancy of the robot’s utility or instrumental functions; therefore the first factor was named *Utility*. The second factor clearly tapped the quickness or clumsiness of the robot’s motion and was named *Clumsiness of motion*. The third factor included expressions of human emotion and the possibility of being friendly through : *Possibility of communication*. The fourth factor captured mastery of the robot that reflected how well it can be mastered by humans: *Controllability*. The fifth concerned worry or anxiety about breaking of the robot: *Vulnerability*. The sixth factor reflected the perceived angularity or solidness of the robot regardless of actual physical hardness: *Objective hardness*.

In the preliminary study we found 8 categories: *Admiration for technology of humanoid robots*, *Expectation of utility*, *Clumsiness of motion*, *Possibility of communication*, *Familiarity*, *Controllability*, *Anxiety about vulnerability*, and *Objective hardness*. In contrast, this study revealed 6 factors. The data suggest that *Admiration for technology of humanoid robots* and *Expectation of utility* can be combined as a single factor of *Utility*. *Possibility of communication*, and *Familiarity* was also combined a single factor.

Table 2 shows reliability, or the consistency of the set of items that make up each factor. The data indicate high consistency of each subscale. Inter-factor correlations are also indicated in Table 2, but more detailed relationships between these factors are investigated later. Table 3 includes descriptive statistics. The items included in each factor were summed and divided by the number of items, and descriptive statistics were calculated. Table 3 showed that as for HRP-2 people felt relatively high *Clumsiness of motion* and *Objective hardness*. In addition, *Possibility of communication* was evaluated low.

We examined the relationships between these factors by using structural equation modeling using Amos 18[13].

TABLE I
ITEMS AND FACTOR LOADINGS OF THE SCALE OF PERCEPTION OF HUMANOID ROBOTS

Item	Factor loading 1	2	3	4	5	6
1.Utility						
This robot makes me feel technology is awesome.	**0.86**	0.06	0.20	-0.09	0.06	-0.08
Science technology has progress enough to make a robot like this.	**0.78**	0.16	0.22	0.05	-0.11	-0.12
This robot will be utilized widely.	**0.67**	-0.08	-0.13	0.20	-0.09	0.11
I am impressed with the way this robot moves.	**0.66**	0.18	0.00	-0.07	0.07	-0.03
This robot is epoch-making.	**0.64**	0.03	-0.12	0.00	0.10	0.11
This robot will be useful for us in various ways.	**0.63**	-0.10	-0.07	0.17	-0.13	0.05
This robot seems useless.	**-0.58**	0.31	0.01	-0.02	0.10	-0.06
This robot habe a high degree of usability for human beings.	**0.54**	-0.17	-0.12	0.10	0.01	0.19
This robot looks strange to me.	-0.42	-0.02	0.03	0.36	0.02	0.21
2.Clumsiness of motion						
This robot is slow.	0.07	**0.94**	-0.07	0.08	-0.02	-0.07
The reactions of this robot aren't quick.	0.05	**0.87**	-0.01	0.01	0.05	-0.06
This robot moves awkwardly.	-0.02	**0.70**	0.04	0.02	-0.10	0.06
The motions of this robot are hesitant.	-0.04	**0.66**	-0.11	0.01	0.04	0.19
This robot seems stiff.	0.12	0.39	0.11	0.06	-0.09	0.32
This robot seems to be able to perform only structured routine.	0.08	0.34	0.20	-0.23	0.00	0.26
This robot moves smoothly.	0.16	-0.32	-0.18	0.08	0.01	-0.09
This robot's expression skills are limited.	-0.15	0.29	0.23	0.18	-0.10	-0.01
3.Possibility of communication						
I feel an affinity toward this robot.	0.14	0.08	**-0.69**	-0.01	0.03	-0.03
This robot is cold unlike human beings.	0.03	0.06	**0.63**	0.15	-0.02	-0.03
This robot is emotionless.	0.09	0.15	**0.60**	0.02	-0.13	-0.11
I could open my heart to this robot.	-0.02	-0.14	**-0.59**	0.17	-0.06	0.02
I don't feel close to this robot.	-0.23	-0.01	**0.58**	0.15	0.02	0.05
I can effectively use this robot.	-0.19	0.15	**-0.58**	0.15	-0.20	0.01
This robot is cold-looking.	-0.03	-0.02	**0.58**	0.19	0.02	-0.08
I think this robot is flexible and can make an appropriate decision according to the situation	0.07	0.05	**-0.49**	0.21	-0.04	0.06
This robot looks nice.	0.32	0.12	**-0.45**	0.00	0.12	-0.11
I can't deal with this robot in the same way that I would with a human being.	0.09	0.19	**0.43**	-0.02	0.03	0.00
This robot looks like a simple piece of metal.	0.14	0.13	0.40	-0.01	-0.02	0.34
It seems to be difficult for me to handle this robot.	0.26	-0.06	0.32	0.03	0.17	0.11
4.Controllability						
I worry about this robot going out of control during my operation.	0.17	-0.03	0.07	**0.82**	0.02	-0.06
This robot will do something unpredictable in case of failure.	0.10	0.09	-0.10	**0.81**	0.03	-0.09
I feel scared that this robot might act on its own when I operate it.	0.01	0.05	-0.11	**0.71**	0.13	-0.06
This robot is frightening because of the feeling of otherness it gives me.	-0.16	-0.11	0.25	**0.42**	-0.05	0.14
This robot makes disagreeable noises when it is moving.	0.02	-0.01	-0.09	0.24	0.08	0.17
5.Vulnerability						
This robot seems easy to break when touched.	-0.15	-0.02	-0.18	0.04	**0.68**	0.08
This robot looks like it might go wrong when it is operated.	0.21	-0.15	0.12	0.02	**0.64**	0.05
This robot seems to be tough enough not to break down easily.	0.06	0.02	-0.04	-0.03	**-0.63**	0.06
This robot is likely to break down any minute.	-0.11	0.12	0.09	0.12	**0.56**	-0.01
I worry about the vulnerability of this robot.	0.02	0.08	0.14	0.12	**0.54**	-0.02
6.Objective hardness						
This robot looks coarse.	-0.04	0.07	-0.01	-0.06	0.03	**0.86**
This robot looks angular.	0.07	0.12	-0.03	0.01	0.02	**0.76**

Note that items in gray cells were deleted for low factor loading. Bold scores indicate the highest loading matching each factor

Fig. 3 shows the results. All path coefficients between variables are significant at $p < .05$. Error variables are not indicated in the figure. The overall fit of the proposed model was examined using the goodness-of-fit index (*GFI*)[14], the adjusted *GFI* index (*AGFI*)[15], the comparative fit index (*CFI*)[16], and the root mean square residual (*RMR*)[15]. Values for the *GFI*, *AGFI*, and *CFI* generally range from 0 to 1 with larger values indicating a better fit of the model to the data. [17] recommend a cutoff of .90 for the *GFI*. For the *AGFI*, [18]suggested that a value of less than .80 can be regarded as inadequate. [16] recommended that values of the *CFI* should not be less than .90. The root mean square residual is an indicator of the model's residual variances and covariances. Small values are indicative of a better fit. The χ^2 statistic can be used to evaluate the goodness-of-fit of a model, with a significant χ^2 suggesting a poor fit. Totally the model in this study showed a good fitness; *GFI* =.997, *AGFI* = .969, *CFI* = .997, *RMR* = .021, and χ^2 = 3.274 (df = 2, p = .185).

TABLE 2
INTER FACTOR CORRELATION AND RELIABILITY

		1	2	3	4	5	6
1(Utility)	*r*		-.31	.41	-.01	-.16	-.03
	p		.01	.01	.85	.01	.55
2(Clumsiness of motion)	*r*			-.54	-.08	.27	.44
	p			.01	.14	.01	.01
3(Possibility of communication)	*r*				.25	-.37	-.46
	p				.01	.01	.01
4(Controllability)	*r*					-.39	-.26
	p					.01	.01
5(Vulnerability)	*r*						.25
	p						.01
	α	.87	.86	.83	.79	.80	.83

Factor 6 is the subscale of objective hardness. *r* is the correlation coefficient and *p* is significance level. Reliability (*α*) is the consistency of the set of items that make up each factor.

TABLE 3
DESCRIPTIVE STATISTIC FOR SUBSCALES

	Min.	Max	Mean	*SD*
Utility	1.00	7.00	4.54	1.08
Clumsiness of motion	1.75	7.00	5.60	1.04
Possibility of communication	1.00	6.60	2.94	0.90
Controllability	1.00	7.00	4.66	1.34
Vulnerability	1.00	7.00	4.39	1.15
Objective hardness	1.00	7.00	5.27	1.35

The arrows represent causal relationships between variables. For instance, *Utility* was strongly enhanced by *Possibility of communication*. Negative coefficients indicate inverse relationships. For example, *Possibility of communication* was decreased by *Clumsiness of motion* and *Objective hardness*, and *Vulnerability* also decreased *Controllability*. Overall, robots' hardness made their movement seem clumsy, and that resulted in low possibility of communication. The possibility of communication with robots enhanced expectation of utility of the robots, whereas objective hardness of robots increased expectation of utility.

Next, we investigated the factor structure of the scale of interpersonal perception when the scale was used for perception of humanoid robots.

Analysis on the item level according to both Kaiser's criterion (eigenvalues > 1.0) and the screeplot yielded 5 factors. Table 4 shows the result of the factor analysis. Many items didn't load on any factors and were finally dropped. The original scale was composed of 3 factors (familiarity, social desirability, and activeness), but the present results reveal 5 factors. For these, it was difficult to interpret what concepts were captured by items in each factor. Compared to the result of PERNOD (cf. Table 2), the reliability of each factor was low, and for factors 4 and 5, reliability could not calculated because of the small number of items. This result of low validity means that perspectives to recognize humanoid robots are not similar to the perspectives to human beings, and also suggested the necessity to develop the scale just for humanoid robots like PERNOD. Overall, the scale for interpersonal perception showed low validity when it was used for the humanoid robot.

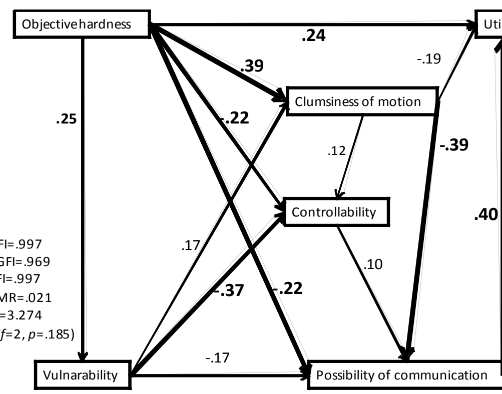

Fig. 3 A model of relationships among basic dimensions of perception to humanoid robots.

TABLE 4
ITEMS AND FACTOR LOADINGS OF THE SCALE OF INTERPERSONAL PERCEPTION USED FOR HUMANOID ROBOTS

	1	2	3	4	5
friendly-unfriendly	**-0.67**	0.10	0.16	-0.10	0.32
amiable-inaccessible	**-0.64**	0.06	0.23	-0.15	0.04
unagreeable-agreeable	**0.63**	0.03	0.23	0.01	-0.02
generous-self-centered	**-0.59**	-0.08	-0.10	0.16	-0.05
bad natured-good natured	**0.52**	0.02	0.30	0.04	0.11
depressed-exhilarated	0.35	0.31	-0.26	-0.07	-0.09
unsociable-sociable	0.32	0.31	0.01	-0.05	0.05
not insolent-insolent	-0.24	0.05	-0.23	-0.15	-0.18
timid-confident	-0.06	**0.81**	-0.05	-0.03	-0.03
brave-coward	-0.03	**-0.57**	-0.11	0.12	-0.13
lethargic-eager	0.04	**0.54**	-0.02	0.06	-0.29
active-passive	0.03	**-0.48**	0.14	-0.22	0.07
easygoing-short-tempered	-0.02	0.15	**-0.56**	0.02	0.18
careless-careful	0.04	-0.01	**0.54**	0.18	-0.02
responsible-irresponsible	0.16	-0.21	**-0.42**	-0.08	0.37
unkind-kind	0.34	0.10	0.35	-0.05	-0.21
serious-frivolous	0.08	0.02	-0.33	-0.02	0.10
hateful-sweet	0.10	0.15	0.06	**0.81**	0.17
brazen-shy	-0.07	-0.22	0.20	0.38	-0.22
discreet-irrational	-0.03	-0.06	-0.28	0.06	**0.65**
α	.75	.67	.53	-	-

IV. CONCLUSIONS

The present study was conducted to investigate the basic dimensions used to perceive humanoid robots and to develop a scale to evaluate perceptions of humanoid robots, PERNOD.

Six basic dimensions in the perception of humanoid robots were found: *Utility*, *Clumsiness of motion*, *Possibility of communication*, *Controllability*, *Vulnerability*, and *Objective hardness*. These dimensions were different from the basic dimensions of interpersonal perception. The 6 dimensions of PERNOD were originally developed for humanoid robots and these factors are related to each other. Thus, these dimensions represent the organization of knowledge used in the recognition of humanoid robots.

The final 33 items of PERNOD demonstrate that the scale has satisfactory psychometric properties. Internal consistency estimates of reliability had relatively high scores compared to those of the scale of interpersonal perception. Each factor was also convergent and the factor structure was clear. This means PERNOD is more appropriate to evaluate humanoid robots than the scale for interpersonal perception that was used in previous studies.

Almost previous studies asked people psychological impressions by means of inappropriate scales or methods like asking question directly not discovering the concepts that researchers wanted know. Therefore, the previous results would have difficulties to be understood in relation to what psychological matters the scores meant strictly. Alternatively, this study clearly identified the basic dimensions in the perception to humanoid robots that is used generally at least by relative young people who are not familiar with humanoid robots. The 6 dimensions of PERNOD reflect important perspectives for ordinal people in the face of humanoid robots. It is necessary to take these dimensions into account in order to evaluate humanoid robots psychologically.

This study suggests that people adopt different perspectives on human beings and humanoid robots in making evaluations or forming impressions. The present study has a few limitations. First, the stimulus movie showed only HPR-2. Although the facilitator in the preliminary study told the participants to imagine generic humanoid robots, it is possible that most items derived from HRP-2. In future research using a variety of humanoid robots to create other scales, the factor structures should be compared to PERNOD. Second, the participants were limited to university students. This means that this scale has validity for young people. Future researches will investigate the validity of using PERNOD for other generations.

ACKNOWLEDGMENT

H. Kamide thanks to Ikuo Daibo, Naoki Kugihara, Yuji Kanemasa, and Junichi Taniguchi for their collection of some of data used in the main study. This research was supported by Global COE Program "Center of Human-Friendly Robotics Based on Cognitive Neuroscience" of the Ministry of Education, Culture, Sports, Science and Technology, Japan.

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