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Tabulation and Analysis of Questionnaire Results of Subjective Evaluation of Seal Robot in Seven Countries

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Abstract—**This paper describes research on a "mental commitment robot". These robots have a different target audience to industrial robots, one that is not so rigidly dependent on objective measures such as accuracy and speed. The main goal of this research is to explore a new area in robotics, with the emphasis on human-robot interaction. In previous research, we classified robots into four categories, which related to their appearance. We then introduced a robot cat and a robot seal, which we evaluated by interviewing a large group of people. The results showed that physical interaction improved their subjective evaluation of the robots. Moreover, *a priori* knowledge of a subject has a considerable influence on the subjective interpretation and evaluation of mental commitment robots. In this paper, we asked several groups of subjects to evaluate the seal robot known as 'Paro' by answering questionnaires that were given out in exhibitions that were held in seven different countries; Japan, U.K., Sweden, Italy, Korea, Brunei and U.S. This paper reports the results of statistical analysis of the evaluation data.**

I. INTRODUCTION

Robots that coexist symbiotically with people are often machines that are meant to affect human emotions, so their design places emphasis on people's subjective evaluation, although they sometimes do physical work [1]. Such robots should be designed as open systems, with consideration given to both the unknown environments where they will operate and the minds of their users, and not as closed systems for predetermined environments, as with industrial robots. Because these are complicated factors that require consideration and sensitivity to people, they cannot be designed by conventional scientific and technological concepts alone [2][3].

We studied and developed artificial emotional creatures as examples of robots that coexist with people [1][3]-[7]. The artificial emotional creatures exist as subsidiaries in everyday life. Their role is similar to that of pets; they form equal relationships with people, they move by both following orders from people and by acting autonomously. When they come into contact with people [8][9], their function is to give pleasure and to aid relaxation. They may prevent mental illness by enriching and healing human emotional responses, they add pleasure to daily leisure time and they commit themselves into the humans' mental faculties. They are referred to as "mental commitment robots".

A 'seal-type' mental commitment robot was applied to the therapy of children at a pediatric hospital and to assisting the activities of elderly people in care institutions as the substitute of real animals in animal therapy [10]-[18]. The results showed that interaction with the seal robot offered psychological, physiological and social merit in these situations. Especially, the neuropsychological effects of Paro on patients with dementia were assessed by analyzing their EEGs [17][18]. The results showed that the activity of the patients' cortical neurons improved by interaction with Paro, especially in the case of those who liked Paro. Real animals have safety and sanitary issues. These results showed that Paro could be a substitute of real animals in animal therapy.

Not only the therapeutic effects, but acceptance of the robot is also important. The studies were conducted using questionnaires given out at exhibitions held in six countries; Japan, U.K., Sweden, Italy, Korea, and Brunei. These were designed to discover how people subjectively evaluate robots during human interaction, a characteristic of mental commitment robots [19]-[24]. The statistical analysis was conducted in each county's data set and found the important evaluation points for the robot. In this paper, we conducted the same study in the exhibition held in the U.S. This paper aims to investigate the differences of the subjective evaluation of the robot in seven countries by extracting the common evaluation points.

The developmental purpose and process of the mental commitment robot are stated in Chapter 2. The method of subjective evaluation is explained in Chapter 3, the results of our statistical analysis of the evaluation data are discussed in Chapter 4 and are finally summarized in Chapter 5.

II. SEAL ROBOT: PARO

A. Mental Commit Robot

Mental commitment robots are not intended to offer people physical work or service. Their function is to engender mental effects, such as pleasure and relaxation, in their role as personal robots. The robots act independently with purpose and with 'motives' while receiving stimulation from the environment, as with living organisms. Actions that manifest themselves during interactions with people can be interpreted as though the robots have hearts and feelings.

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Fig.1 Paro, the Seal Robot

Fig. 2 Demonstration at the City Hall, Kyonjyu, Korea

Fig. 3 Demonstration at the Jacob Javits Center, NYC, the U.S.

B. Previous Process

A basic psychological experiment was conducted on the subjective interpretation and evaluation of robot behavior following interactions between robots and people. This showed the importance of appropriately stimulating the human senses and extracting associations. Sensor systems, such as visual, aural and tactile senses for robots, were studied and developed. A plane tactile sensor using an air bag was developed to cover the robot in order to enhance bodily contact between people and robots. This can detect position and force when people touch the robot, and at the same time, it allows people to feel softness. Dog, cat and seal robots were developed using these sensors.

In the subjective evaluation of mental commitment robots reported in this paper, a mental commitment seal robot known as "Paro" was used.

C. Seal Robot "Paro"

The robot and its major functions are shown in Fig.1. Its appearance was designed using a baby harp seal as a model, and its surface was covered with pure white fur. A newly-developed plane tactile sensor was inserted between the hard inner skeleton and the fur to create a soft, natural feel and to permit the measurement of human contact with the robot [25]. The robot is equipped with the four primary senses; sight (light sensor), audition (determination of sound source direction and speech recognition), balance and the above-stated tactile sense. Its moving parts are as follows: vertical and horizontal neck movements, front and rear paddle movements and independent movement of each eyelid, which is important for creating facial expressions. The robot operates by using the 3 elements of its internal states, sensory information from its sensors and its own diurnal rhythm (morning, daytime, and night) to carry out various activities during its interaction with people.

III. Purposes and Method of Subjective Evaluation

A. Purpose of Subjective Evaluation

In a previous study, a subjective evaluation of seal robots was carried out by questioning in Japan, U.K., Sweden, Italy, Korea, and Brunei [19]-[24]. The statistical analysis was conducted in each county's data set and found the important evaluation points for the robot. The objectives of this paper were to gather and evaluate information from questionnaires that were given to a large number of interviewees in the U.S. and investigate the differences of the subjective evaluation of the robot in seven countries by extracting the common evaluation points and compare the results. It was also intended to collect requests, opinions and impressions of the development of mental commitment robots that might be used for future R&D.

Ogata et al. and Kanda et al. conducted similar subjective evaluation experiments with multiple respondents about a mechanical robot. This was evaluation on communication with the robot [26][27]. The present paper differs in that its goal is to study as to how subjective evaluation is affected by the appearance of a seal robot that is easily associated with this animal, a soft structure designed to think of much of contacting, and the interaction of bodily contact.

B. Method of Subjective Evaluation

The seal robots (Paro) were displayed at the following seven exhibitions, which were held in different countries.

- "Exhibition of Dream Technology," Tokyo Big Sight, Tokyo, Japan, July 21-Aug. 6, 2000
- "Japan: Gateway to the Future, Digital Technology Exhibition," the Science Museum, London, U.K., Feb. 1 - Mar. 16, 2002
- "Robotics Exhibition," the National Museum of Science and Technology, Stockholm, Sweden, May 10, 2003 – May 10, 2006
- "Robotics Exhibition," the Japan Cultural Institute, Rome, Italy, June 25-28, 2003
- "Intelligent Robot Contest," the City Hall, Kyonjyu, Korea, October 2-5, 2003 (Fig.2)
- "Brunei International Trade Exhibition," the Exhibition Center, Brunei, February 28-March 3, 2004
- "WIRED NextFest 2006," the Jacob Javits Center, NYC, U.S. September 28 – October 1, 2006 (Fig.3)

The demonstration took place throughout the whole period of the exhibitions, so 1, 2 or 3 Paro were prepared before the experiments.

The details of the demonstrations were the same at each exhibition. Demonstrators on a stage conducted somewhere more then one display each day. After they had explained the developmental process and the purpose and functions of the mental commitment robots, Paro was placed on the table to allow the audience to visit the stage and to touch the robot freely. A questionnaire was offered to the visitors after the interaction, and those who accepted it were asked to fill out a form. A total of 785 questionnaires were returned in Japan, 440 in the U.K., 133 in Sweden, 95 in Italy, 180 in Korea, 98 in Brunei and 123 in the U.S.

1) Questionnaire

The contents of the questionnaires were written in the native language of each country and were broadly classified into questions about the respondent (Table I) and a 5-grade evaluation for subjective evaluation (Table II). The time taken to answer the questionnaire time differed from person-to-person, but 5-10 minutes was normal. Many children were included, so parents were requested to help them in answering their questionnaires.

2) Condition of Demonstration (Interaction)

Paro was placed on a table to allow visitors to the stage or the display booth to interact freely with it. The front of the stage or the display booth could sometimes become quite crowded, but each cycle of the demonstration lasted for about 30 minutes to permit as many people as possible to experience the interaction in turn.

The interactions mainly involved the actions of contacting and stroking, and women hugged it in some cases. In other cases, visitors called its name, or brought their faces close to it. There were no big differences between each country.

TABLE I. QUESTION ABOUT SUBJECTS

Personal Questionnaire
1. Sex?
2. Age?
3. Occupation?
4. Do you like animals?
5. Are you owning any pets or do you want to own pets?
6. Why do you no have any pets?
7. Do you know about real baby seals?

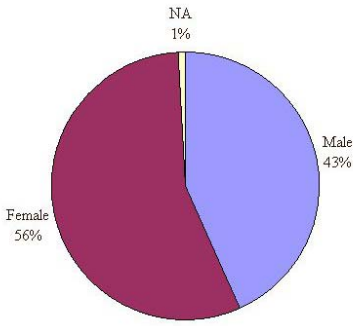
TABLE II. QUESTION ABOUT SUBJECTIVE EVALUATION OF PARO

Evaluation Questionnaire
1. Cute
2. I want to pet it
3. I want to talk to it
4. Lively
5. Friendly
6. Expressive
7. Natural
8. Feels good to the touch
9. Fun to play with
10. Relaxing
11. Like
12. Needed in this world
13. I want it for myself

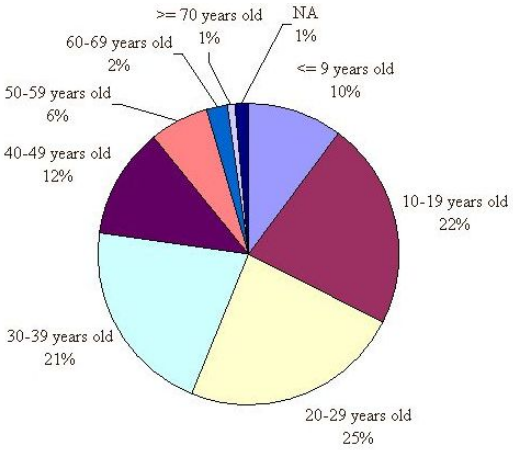
IV. RESULTS AND DISCUSSION

A. Answer Results of Questionnaires

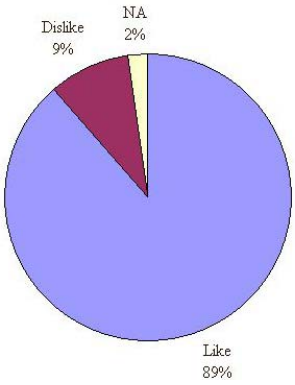
Fig.4 (a), (b) and (c) shows the gender, age and like/dislike of animals of respondents filling out questionnaires. Fig.5 shows the average values and standard deviations of the answers to the 13 questions in the subjective evaluation given by respondents in Japan (641), U.K. (320), Sweden (111), Italy (76), Korea (118), Brunei (83) and U.S. (70) (the numbers in brackets show the respondents who filled out complete answers to the 13 questions). The results of the subjective evaluations from all countries indicate that favorable answers were obtained for the most part, and the variables "Cute," "I want to pet it," and "Like" were evaluated highly. The overall results were very similar from all of the countries. The variable "I want to talk to it" was



(a) Distribution by gender



(b) Distribution by age



(c) Distribution by like/dislike of animals

Fig. 4 Proportion of gender, age and like/dislike of animals

evaluated lower in the U.K. Sweden and Italy than it was in other countries, but this was probably because Paro could not understand the native language of the countries at that point.

B. Principal Component Analysis of Subjective Evaluation

Multivariate analysis was conducted to comprehensively evaluate the answers given in the subjective evaluation. There was no external criterion in the analysis, and the contents of all 13 questions were explanatory variables for the evaluation of Paro. The multivariate analysis techniques that are applicable for such variables include principal component analysis, factor analysis and latent structure analysis.

Principal component analysis was used to carry out a comprehensive evaluation using the 13 explanatory variables, because the cumulative contribution becomes higher than in the case of extracting the same number of factors by factor analysis. This analysis was conducted using only sheets containing complete answers to the 13 questions from each of the countries.

C. Results and Discussion of the Principal Component Analysis

Principal component analysis was carried out using sheets with complete answers to the 13 questions posed in the subjective evaluation to extract factors until the total variance was over 60%. Kaiser normalization was carried out to enhance the factor interpretation, and then two factors characterized by the factor loading shown in Table III were obtained.

1) Interpretation of Factors

The first factor is characterized by the variables "Lively," "Expressive," "Natural," "Feels good to the touch," and "Relaxing," and it can be interpreted as a factor involving "comfortable feeling like interacting with real animals." The second factor is characterized by "Cute," "I want to pet it," "I want to talk to it," and "I want it for myself," and it can be interpreted as a factor involving "favorable impression to encourage interaction."

2) Comparison of Factor Scores

To analyze the factor scores in detail, the respondents were grouped and the average factor scores were compared between the groups. Grouping was carried out for gender and like/dislike of animals, and the factor score of each group was subjected to Wilcoxon's test. This is a non-parametric test to test the mean difference, since normality or equal variance would not be expected for each group. A comparison of the factor score averages between the proportions of the number of respondents in each group is shown in Fig.6 (a) and (b).

When grouped by gender, significant differences were seen in the score for the both factor, where women tended to give a higher evaluation. When grouped by like/dislike of animals, significant differences were also seen in the score of the both factor. The people who like animals evaluated these highly.

In addition, to analyze the difference in the seven countries, the factor scores were grouped by countries. Fig.7 shows the scatter diagram of the average factor scores of each country. The horizontal axis is the factor "comfortable feeling like interacting with real animals," and the vertical axis is the factor "favorable impression to encourage interaction." As the results, people in Japan and Korea tended to give a higher evaluation in the factor "favorable impression to encourage interaction." On the other hand, people in the U.K. Sweden, and especially Italy, tended to give a higher evaluation in the factor "comfortable feeling like interacting with real animals." As for the people in Brunei and the U.S. evaluated in the both factors highly.

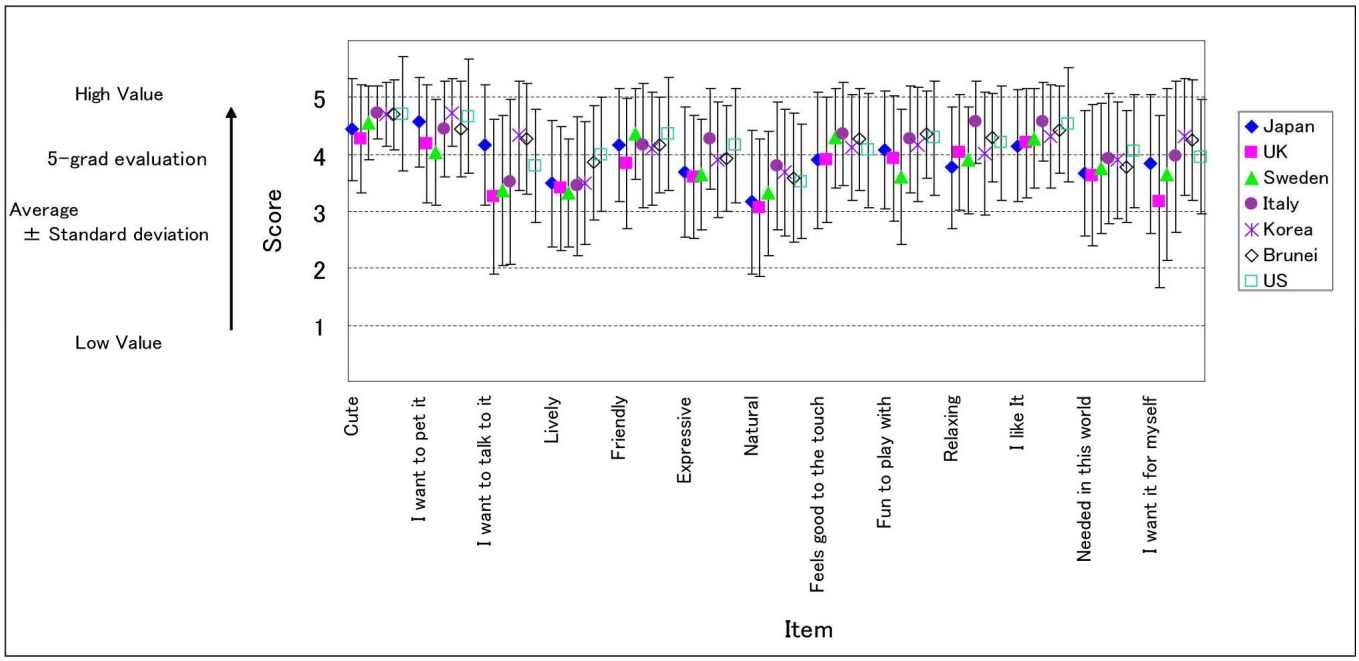


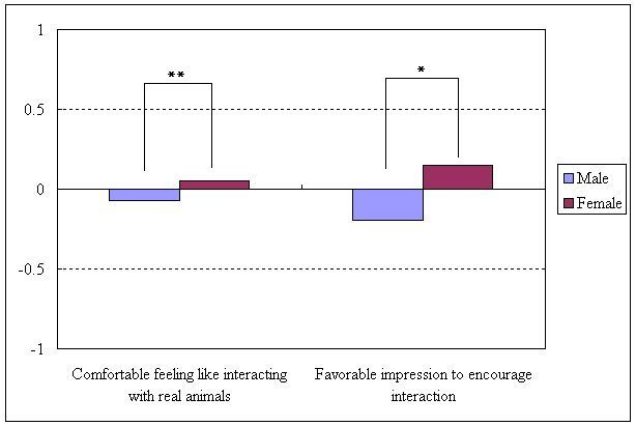
Fig.5 Average and standard deviation of answers to 13 questions about subjective evaluation in Japan (641 sheets); U.K. (320 sheets); Sweden (111 sheets); Italy (76 sheets); Korea (118 sheets); Brunei (83 sheets); and the U.S. (70)

TABLE III. FACTORS CHARACTERIZED BY FACTOR LOADING

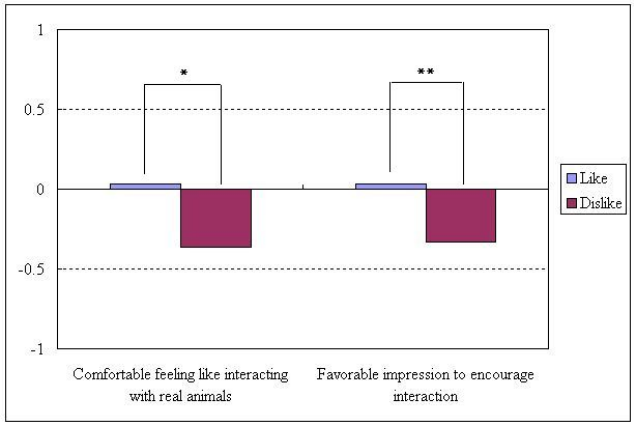
Variable	Factor 1	Factor 2
Cute	0.423	0.664
I want to pet it	0.199	0.831
I want to talk to it	0.213	0.786
Lively	0.623	0.317
Friendly	0.582	0.481
Expressive	0.748	0.254
Natural	0.794	0.230
Feels good to the touch	0.690	0.265
Fun to play with	0.568	0.550
Relaxing	0.758	0.257
I like it	0.580	0.592
Needed in this world	0.551	0.337
I want it for myself	0.438	0.633
%Total variance	33.7	60.7

V. CONCLUSION

Seal robots, known as “Paro”, were introduced to a large number of visitors in robot exhibitions in seven countries; Japan, U.K., Sweden, Italy, Korea, Brunei and the U.S. After the interaction with Paro was completed, questionnaires were provided to undertake a subjective evaluation of Paro. On the whole, the results of tabulating the subjective evaluation provided high scores, and were very similar in each country. In addition, important factors that will become key points in robot evaluation were extracted from the results of the principal component analysis. These results revealed that the evaluation factors “comfortable feeling like interacting with real animals” and “favorable impression to encourage interaction” are important. The respondents were then



(a) Comparison by gender



(b) Comparison by like/dislike of animals

Fig.6 Comparison of the factor score average

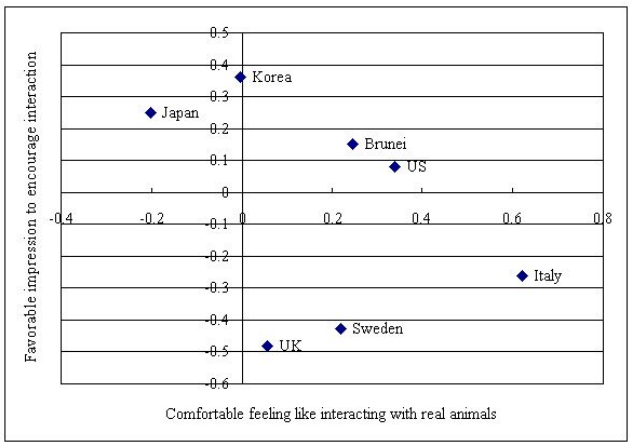


Fig. 7 Comparison of factor score average in each country

grouped to find differences in the evaluations among the groups. The people in Europe (the U.K., Sweden and Italy) highly evaluated in the factor "comfortable feeling like interacting with real animals." We considered they tended to associate with animals through interaction with Paro than other counties and then, therapeutic effect which animals have would emerge on them easily. On the other hand, the people in Asia (Japan and Korea) highly evaluated in the factor "favorable impression to encourage interaction." We expect Paro would be acceptable as their pets for fun more than a therapeutic tool in those Asian countries. The results of the requests and impressions obtained in the questionnaires will be used for the improvement of Paro.

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