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Questionnaire Results of Subjective Evaluation of Seal Robot at the National Museum of Science and Technology in Stockholm, Sweden

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ABSTRACT: This paper describes research on mental commit robot that seeks a different direction from industrial robot, and 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 an emphasis on human-robot interaction. In the previous research, we categorized robots into four categories in terms of appearance. Then, we introduced a cat robot and a seal robot, and evaluated them by interviewing many people. The results showed that physical interaction improved subjective evaluation. Moreover, a priori knowledge of a subject has much influence into subjective interpretation and evaluation of mental commit robot. In this paper, 133 subjects evaluated the seal robot, Paro by questionnaires in an exhibition at the National Museum of Science and Technology in Stockholm, Sweden. This paper reports the results of statistical analysis of evaluation data.

Keywords: human robot interaction, subjective evaluation, mental commit robot, seal robot, statistical analysis

1. Introduction

Robots that coexist symbiotically with people are machines to affect human hearts and lay stress on people's subjective evaluation, although they sometimes do physical work [1]. Such robots should be designed as open systems considering unknown environment and the minds of users, not as closed systems and predetermined environments as with industrial robots. Because these are complicated requiring consideration to people and sensitivity, they cannot be designed by conventional scientific and technological concepts alone [2, 3]

We studied and developed artificial emotional creatures as the examples of robots that coexist with people [1, 3-6]. The artificial emotional creatures exist as subsidiaries in everyday life similar to pets, hold equal relationships with people, move by orders from people and act autonomously, and contact with people [7], giving people pleasure and relaxation. They prevent mental illness by enriching and healing the humans' heart, give pleasure to daily leisure, and commit themselves to the humans' mental part. They are referred to as "mental commit robots".

Seal type mental commit robot was applied to therapy of children at pediatric hospital and assisting activity of elderly people at elderly institutions [6, 8-12]. The results showed that there were psychological merit, physiological merit, and social merit by interaction with the seal robot.

A study was conducted by questionnaires in "Exhibition of Dream Technology" held for about 3 weeks from July to August 2000, on how people subjectively evaluate robots in human interaction, a characteristic of mental commit robots [13]. Seal robots were used for evaluation. Respondents were exhibition visitors, and after demonstrators explained the purpose and functions of the robot, they were requested to interact with the robot. Multiple questions about the robot were asked by questionnaires. The tabulation results of subjective evaluation provided high evaluation on the whole. In addition, important factors to be key points in robot evaluation were extracted from the results of principal component analysis, thus confirming relationship between them and factors such as shape and the feel emphasized in design. Respondents were grouped to find differences in evaluation among groups. These results revealed that the evaluation factors of "favorable impression by contacting" and "favorable impression by appearance" are important as those pertaining to evaluation in the design and production of mental commit robots to be highly appreciated in subjective evaluation.

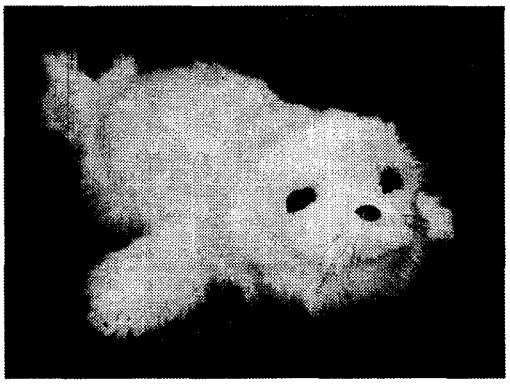


Fig.1 Seal Robot: Paro

Another study was conducted by questionnaires in "Japan: Gateway to the Future, Digital Technology Exhibition" held for about 7 weeks from February to March 2002 at the Science Museum in London, U.K., on how people subjectively evaluate robots in human interaction, a characteristic of mental commit robots. The way of study was the same as the previous one. The tabulation results of subjective evaluation provided high evaluation on the whole, and were very similar in those of Japan [14].

This time, we obtained an opportunity to exhibit the seal robots for 3 years from May 2003 to May 2006 in Robotics exhibition at the National Museum of Science and Technology in Stockholm, Sweden. The same study was conducted by questionnaires in the Museum for 7 days. This paper reports results of statistical analysis of evaluation data.

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

2. Seal Robot: Paro

2.1. Mental Commit Robot

Mental commit robots are intended to offer people not physical work or service but mental effects such as pleasure and relaxation as personal robots. Robots act independently with purposes and motives while receiving stimulation from the environment as with living organisms. Actions manifested by interaction with people are interpreted by people as if robots have hearts and feelings.

2.2. Previous Process

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

In the subjective evaluation of mental commit robots in this paper, a mental commit seal robot "Paro" version 7 was used.

2.3. Seal Robot "Paro"

The robot and major functions are shown in Fig.1. The appearance was designed with a harp seal baby as a model, and the surface is covered with pure white fur. A newly developed plane tactile sensor is inserted between the hard inside skeleton and fur to express the soft natural feel and to permit the measurement of human contact with the robot. The robot has the 4 senses of sight (light sensor), audition (determination of sound source direction and speech recognition), and equilibrium in addition to the above-stated tactile sense. Mobile parts are as follows: vertical and horizontal neck movements; front and rear paddle movements; and each eyelid movement important as facial expression. The robot acts by using the 3 elements of the internal states of the robot, sense information from sensors, and daily rhythm (morning, daytime, and night) to manifest activities through interaction with people.

3. Purposes and Method of Subjective Evaluation

3.1. Purpose of Subjective Evaluation

In the previous studies, subjective evaluation was done with cat robots for 88 respondents and seal robots for 785 respondents in Japan, and 440 respondents in U.K. The objectives of this paper were that questionnaires from a lot of persons in Stockholm, Sweden, were conducted on a large scale to collect subjective evaluation data about interaction with robots and analyze them statistically, thus analyzing and classifying the tendency of robot evaluation and elements as evaluation points. It was also intended to collect requests, opinions, and impressions to the development of mental commit robots that are used for future R&D.

3.2 Method of Subjective Evaluation

In Robotics exhibition hold at the National Museum of Science and Technology in Stockholm, Sweden for three years from May, 2002 to May, 2006, seal robots Paro are displayed. Demonstration is to be done through the whole period, so 3 Paros were prepared before experiments.

On the stage, demonstrators conducted one to three demonstrations a day in weekends. After the developmental process and purpose and the functions of mental commit robots etc. were explained for about 5 minutes, Paro was placed on the table to allow the audience who visited the stage to touch the robot freely. A questionnaire was given to visitors who after interaction, and accepted this filled out the form. Total 133 questionnaires were obtained during the 7 days in weekends in May and June, 2003.

Fig. 2 Demonstration at the National Museum of Science and Technology in Stockholm

Table 1 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 not have any pets?
7. Do you know about real baby seals?
8. How much free time do you have in daily life?

Table 2 Question about Subjective Evaluation of Paro

Evaluation questionnaire
1. Cute
2. Want to pet it
3. Want to talk to it
4. Has vitality
5. Easy to get friendly with
6. Has real expressions
7. Natural
8. Feels good to the touch
9. Fun to play with
10. Relaxing
11. Like
12. Needed in this world
13. Want it for myself

3.2.1. Questionnaire

The contents of the questionnaire are written in Swedish, and classified largely into questions about the respondent (Table 1); and questions of 5-grade evaluation for subjective evaluation (Table 2). The answer time was different from person to person, but 5-10 minutes were necessary. Many children were included, so parents were requested to help them in answering questionnaires.

3.2.2. Condition of Demonstration (Interaction)

Paro was placed on the table to allow visitors to the stage to interact freely with it. The front of the stage was sometimes quite crowded and yet every cycle of demonstration took about 30 minutes to permit as many people as possible to experience interaction by turn.

Interaction 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.

4. Results and Discussion

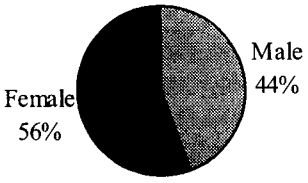
4.1. Answer Results of Questionnaires

Fig.3 (a) and (b) show the proportion of gender and age of 111 respondents who filled out complete answers to 13 questions. Fig.4 gives the values of average and standard deviation of answers to the 13 questions of subjective evaluation at the National Museum of Science and Technology in Stockholm, Sweden. The results of subjective evaluation in Sweden indicate that favorable answers were obtained for the most part, and the variables of "Cute," "Easy to get friendly with," "Feels good to the touch," and "Like" are highly evaluated.

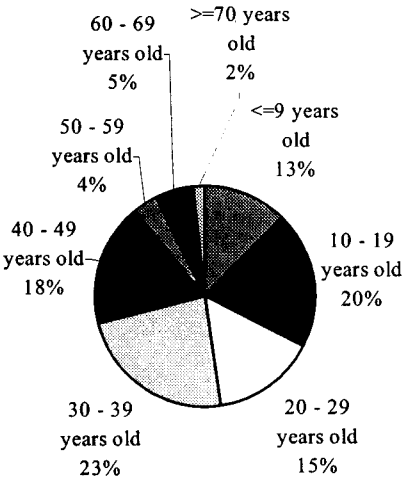
4.2. Principal Component Analysis of Subjective Evaluation

Multivariate analysis was conducted to evaluate the answers of subjective evaluation comprehensively. In analysis, there is no external criterion and the contents of all 13 questions are explanatory variables for Paro evaluation; the multivariate analysis techniques of such variables include principal component analysis, factor analysis, and latent structure analysis.

Principal component analysis was used to do comprehensive evaluation by 13 explanatory variables, and because cumulative contribution becomes higher than the case of extracting the same number of factors by factor analysis. This analysis was conducted with 111 sheets consisting of complete answers to 13 questions.



(a) Distribution by Gender



(b) Distribution by Age

Fig. 3 Proportion of Gender and Age of Respondents

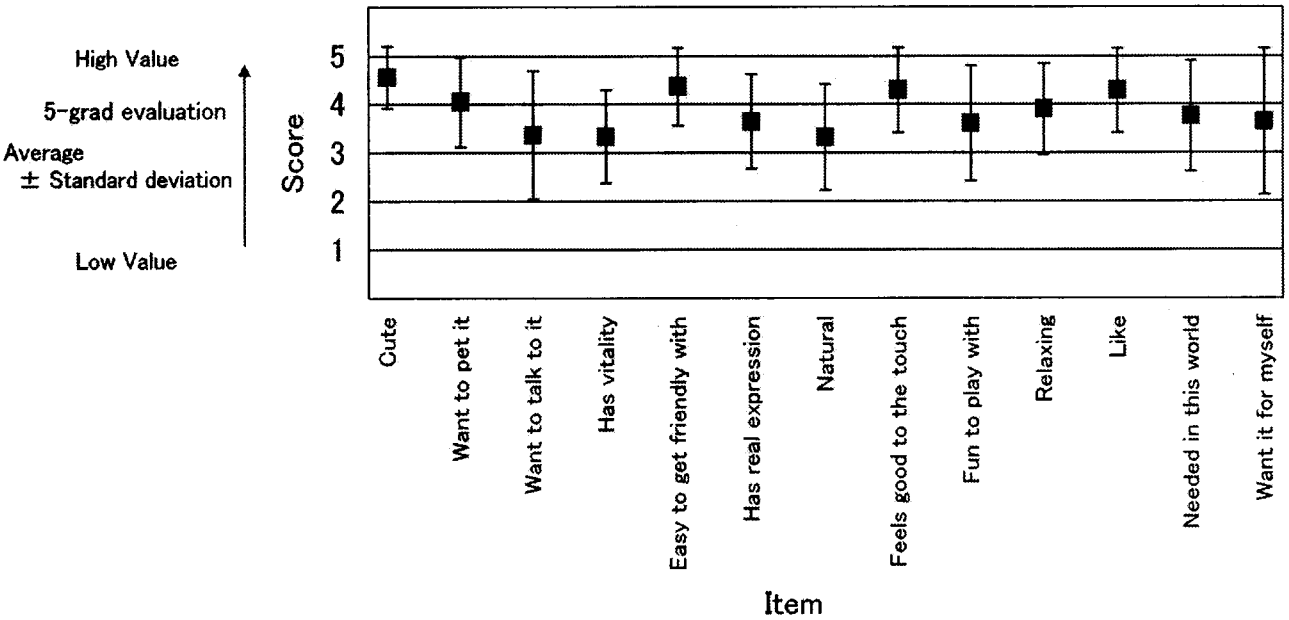
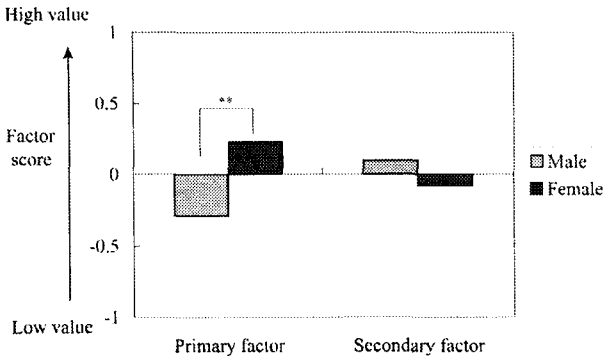
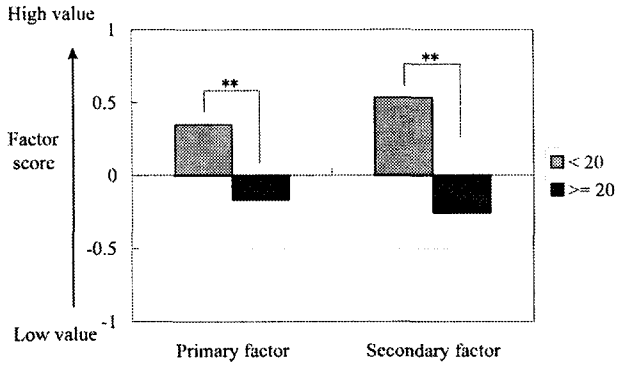


Fig. 4 Average and Standard Deviation of Answers to 13 Questions about Subjective Evaluation in Stockholm, Sweden (111 sheets)



(a) Comparison by Gender



(b) Comparison by Age

Fig. 5 Proportion of Number of Each Group Member and Comparison of Factor Scores Average

4.3. Results and Discussion of Principal Component Analysis

The principal component analysis was done with 111 sheets of complete answers to 13 questions of subjective evaluation to extract two factors with eigen-value of 1 or higher. Kaiser normalization was done to enhance factor interpretation, and then two factors characterized by factor loading.

4.3.1. Interpretation of Factors

The first factor is characterized by the variables of "Cute," "Easy to get friendly with," and "Like," and it can be interpreted as a factor of "overall favorable impression." The second factor is characterized by "Has vitality," "Has real expressions," and "Natural," and it can be interpreted as a factor of "impression like real animals."

4.3.2. Comparison of Factor Scores

In the next step, when the factor scores of the factor of "overall favorable impression" and the factor of "impression like real animals" were calculated to obtain the results of actual evaluation, the distribution of factor score for the whole respondents (111).

To analyze factor scores in detail, respondents were grouped and average factor scores were compared between groups. Grouping was done with gender and age, and the factor score of each group was subjected to Wilcoxon's test, a nonparametric test as a test for mean difference, because the normality or equal variance of each group cannot be expected. The comparison of factor score averages between proportions of respondent number of each group is shown in Fig.5.

In grouping by gender, a significant difference was seen in the score for the factor of "overall favorable impression", and women tended to give it high evaluation. In grouping by age, both factors were significant, and the group of less than 20 years old tended to evaluate it highly.

5. Conclusion

A seal robot, "Paro," was introduced to a lot of visitors in robot exhibition at the National Museum of Science and Technology in Stockholm, Sweden, and interaction with Paro was done to ask questionnaires about the subjective evaluation of Paro.

The tabulation results of subjective evaluation provided high evaluation on the whole. In addition, important factors to be key points in robot evaluation were extracted from the results of principal component analysis. Then, respondents were grouped to find differences in evaluation among groups. These results revealed that the evaluation factors of "overall favorable impression" and "impression like real animals" are important as pertaining to evaluation in the design and production of mental commit robots to be highly appreciated in subjective evaluation in Sweden. Comparison between the results in Sweden and those in Japan and U.K. will be explained in the future.

These results as requests and impressions obtained in questionnaires will be used for the improvement of Paro.

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