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Analysis of Factors that Bring Mental Effects to Elderly People in Robot Assisted Activity

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Abstract

We have been developing mental commit robots that provide psychological, physiological, and social effects to human beings through physical interaction. The appearances of these robots look like real animals such as cat and seal. We have been applied mental commit robots to assisting activity of elderly people at a day service center. In order to investigate the effect of mental commit robots to the elderly people, and to analyze factors that bring effects to them, we evaluated elderly people's mood by questionnaires, and we investigated their experience of breeding pets, interaction with the robots and so on. Mental commit robots were provided into the day service center for five weeks. As the results, feelings of elderly people were improved by interaction with the robots. As for analysis of factors that bring mental effects to the elderly, we found "time of touch divided by number of touch" in 2nd week, and "experiences of breeding pets" in 5th week. Consequently, mental commit robots were useful at elderly institutions like the day service center, and the factors of mental effects on elderly people changed from freshness of stimuli of the robots to feelings of breeding the robots like real animals.

1. Introduction

Most advanced countries are becoming to be aging societies [1]. The number of elderly people who need nursing because of dementia, bedridden, and so on, has been increasing. Moreover, nursing staff's body and mental poverty by manpower shortage and increasing of load is becoming a big problem. Especially, mental stress of nursing causes Burnout syndrome [2]. It makes nursing staff into irritation and losing sympathy to patients. Therefore, it is important to improve "quality of life (QOL)" of elderly people because this helps them to spend their life healthily and independently. It also saves social cost for elderly people.

Animal assisted therapy and activity are becoming popular at hospital and nursing home, especially in the United States [3]. A doctor or nurse makes a program for therapy. Following three effects are expected in animal assisted therapy and activity:

(1) Psychological effect (e.g. relaxation, motivation)
(2) Physiological effect (e.g. improvement of vital sign)
(3) Social effect (e.g. activation of communication among inpatients and caregivers)

In addition to these effects, animal assisted therapy at nursing homes brings effect of rehabilitation to elderly people who have decreased his moving ability, and offers laughter and enjoyment to a patient who has few remainders of his life [4]. Moreover, there are some cases that the therapy improved state of elderly people who were dementia.

However, most hospitals and nursing homes, especially in Japan, don't accept animals even though they admit effects of animal assisted therapy and activity. They are afraid of negative effects of animals to human beings such as allergy, infection, bite, and scratch.

We have been building animal type robots as examples of artificial emotional creatures [5-13]. The animal type robots have physical bodies and behave actively while generating goals and motivations by themselves. They interact with human beings physically. When we engage physically with an animal type robot, it stimulates our affection. Then we have positive emotions such as happiness and love, or negative emotions such as anger and fear. Through physical interaction, we develop attachment to the animal type robot while evaluating it as intelligent or stupid by our subjective measures. In this research, animal type robots that give mental value to human beings are referred to as "mental commit robot." We have developed cat robot and seal robot as the mental commit robot.

We have applied seal robots as substitution of real animals to therapy of children at a university hospital [12]. This was referred to as robot-assisted therapy (RAT). Moods of children were improved by interaction with the robot. Moreover, the robot encouraged children to communicate with each other and caregivers. In one striking instance, a young autistic patient recovered his appetite and his speech abilities during the weeks when the robot was at the hospital. In another case, nurses noted the rehabilitative benefits for a long-term patient,

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unable to leave her bed, who was willing to stroke and pet the animal.

In addition, we have applied seal robots to robot-assisted activity (RAA) for elderly people [13]. The robots improved their moods and brought vigor to them. Moreover, nursing staff's mental poverty decreased because the elderly people spent their time by themselves with the robots.

In this paper, we aimed to investigate factors that bring effects to elderly people in the RAA.

Chapter 2 explains a seal robot that was used for RAA. Chapter 3 describes ways of experiments and explains the effects of RAA to elderly people. Chapter 4 explains analysis of factors that bring the effects to elderly people. Chapter 5 discusses current results of RAA and future works. Finally, chapter 6 concludes this paper.

2. Specifications of Seal Robot

Seal robot, Paro was developed to have physical interaction with human beings. Paro's appearance is from a baby of harp seal, which has white fur for three weeks from its born. As for perception, Paro has tactile, vision, audition, and posture sensors beneath its soft white artificial fur. In order for Paro to consist of a soft body, an air-bag type tactile sensor was developed and implemented. As for action, it has eight actuators; two for upper and lower eyelids, one for rotation of eyes, two for neck, one for each front fin, and one for two rear fins. Weight of Paro is 2.8 [kg].

Paro has a behavior generation system that consists of hierarchical two layers of processes: proactive and reactive processes. These two layers generate three kinds of behaviors; proactive, reactive, and physiological behaviors:

(1) Proactive Behaviors: Paro has two layers to generate its proactive behaviors: behavior-planning layer and behavior-generation layer. Considering internal states, stimuli, desires, and a rhythm, Paro generates proactive behaviors.

(a) Behavior-planning layer: This has a state transition network based on internal states of Paro and Paro's desire produced by its internal rhythm. Paro has internal states that can be named with words of emotions. Each state has numerical level and is changed by stimulation. The state decays by time. Interaction changes internal states and creates character of Paro. The behavior-planning layer sends basic behavioral patterns to behavior-generation layer. The basic behavioral patterns include some poses and some motions. Here, although "proactive" is referred, proactive behaviors are very primitive compared with those of human beings. We implemented similar behaviors of a real seal into Paro.

(b) Behavior generation layer: This layer generates control references for each actuator to perform the

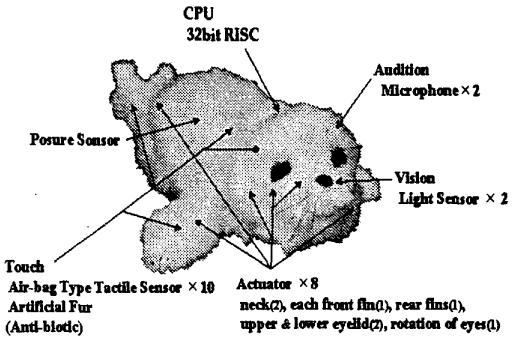

Fig.1 Seal Robot "Paro"

determined behavior. The control reference depends on strength of internal states and their variation. For example, parameters change speed of movement, and the number of the same behavior. Therefore, although the number of basic patterns is countable, the number of emerging behaviors is uncountable because numeral parameters are various. This creates living like behaviors. In addition, as for attention, the behavior-generation layer adjusts parameters of priority of reactive behaviors and proactive behaviors based on strength of internal states. This function contributes to situated behavior of Paro, and makes it difficult for a subject to predict Paro's action.

(c) Long-term memory: Paro has a function of reinforcement learning. It has positive value on preferable stimulation such as stroked. It also has negative value on undesirable stimulation such as beaten. Paro put values on relationship between stimulation and behaviors. Gradually, Paro can be shaped to preferable behaviors of its owner.

(2) Reactive behaviors: Paro reacts to sudden stimulation. For example, when it hears big sound suddenly, Paro pays attention to it and looks at the direction. There are some patterns of combination of stimulation and reaction. These patterns are assumed as conditioned and unconscious behaviors.

(3) Physiological behaviors: Paro has a rhythm of a day. It has some spontaneous desires such as sleep based on the rhythm.

3. Robot Assisted Activity for Elderly People

We applied Paro to robot-assisted activity for elderly people at a day service center in order to investigate its effects on elderly people. The day service center is an institution that aims to decrease nursing load of a family by keeping elderly people in daytime (9:00-15:30). Services, such as bathing, massage, physical exercise and games, are provided to the elderly people there.

Before starting the robot-assisted activity, we explained the purposes and ways of the experiment to the

elderly people, and received their approval.

Symptoms of the elderly people who approved the investigation were various with different reasons (no answer to questionnaires, bedridden, etc). Some people were impossible to be investigated. Then, a nursing staff that knew usual states of the elderly people well evaluated them, and decided who could be investigated. After the evaluation, the number of subjects was 26. All of the subjects were women whose ages were from 73 to 93 years old. There were some subjects who were dementia. Then, the nursing staff judged each dementia's level of subjects in terms of the revised Hasegawa's dementia scale (HDS-R). Their dementia's levels were as follows:

(1) Non-dementia: 16 people,
(2) Slightly degree: 3 people,
(3) A little high degree: 3 people, and
(4) High degree: 4 people.

3.1. Ways of activity

Paro was provided to the elderly people at the day service center three days a week for five weeks. Because they didn't come there every day, they interacted with Paro from one to three days a week. We prepared a desk to set the robot in the center of people, and the elderly people were arranged up to eight people or less as shown in Fig.2. If there were elderly people more than eight, they were divided into two groups randomly. A group interacted with Paro first, and then the other group interacted. The elderly people interacted with Paro about 20 minutes at a time. When the number of people was small, elderly people could interact with Paro about 40 minutes, if they wanted to do.

3.2. Ways of Evaluation

In order to investigate elderly people's moods before and after interaction with Paro, the following two kinds of data and extra information were collected.

(1) Questionnaires concerning moods
(2) Comments of nursing staffs

Profile of Mood States (POMS) is one of popular questionnaires, which measures person's moods [14]. POMS is used in various research fields such as medical therapy and psychotherapy. However, it needs a lot of time to answer questionnaires, because it has many items. Since investigation time at the day service center was limited, and the elderly people had to be able to answer in a short time, we made questionnaires that consisted of six items pulled out from POMS. We selected each two items that have high factor loading against three factors of POMS: Tension-Anxiety, Depression-Defection, and Vigor. The selected items were the following six: Tense, uneasy, vigorous, full of pep, lonely, and unhappy. These items were evaluated by five stages of 0-4 as well as POMS: 0 = not at all, 1 = a little, 2 = moderately, 3 = quite a bit, and 4 = extremely.

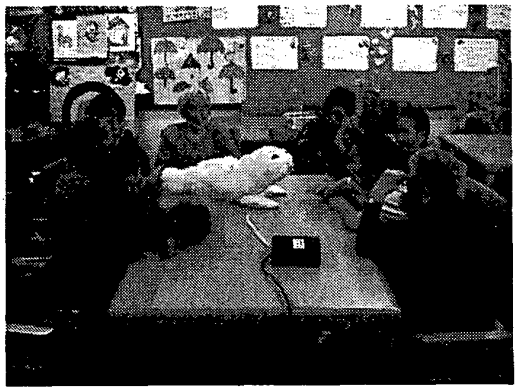

Fig.2 Interaction between Elderly People and Paro

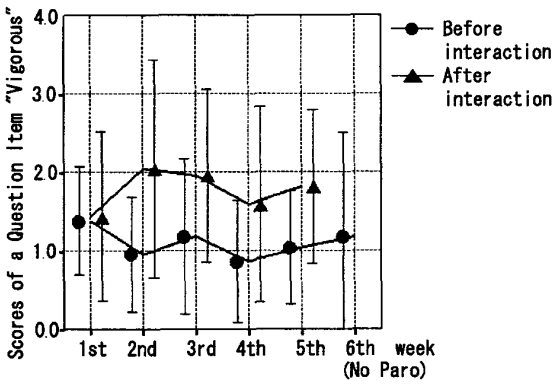

Fig.3 Results of Average Scores of a Question Item "Vigorous" of Elderly People for 6 Weeks

3.3. Results of Evaluation

The questionnaires concerning moods were applied to elderly people, before and after interaction with Paro. In order to examine their moods after Paro had gone, they were also investigated in sixth week without introducing Paro.

As for questionnaires concerning moods, we obtained data from 11 people. Fig.3 shows average of a result of "vigorous" that was one of the questionnaires' items. High score of item expressed that people felt strong in their moods. Scores of after interaction change from about 1.4 to 2.0. However these scores were higher than those of before interaction at after the second week. As a statistic analysis, we applied Wilcoxson's sing rank sum test to the scores of before and after interaction in every week. As a result, significant changes were seen in 2nd, 3rd, 4th and 5th week ($p < 0.05$). Moreover, the score of the sixth week when Paro didn't exist was lower than the scores after interaction with Paro in the previous weeks. Therefore, Paro brought "vigor" to elderly people by interaction, and its effect kept for five weeks. As for "full of pep", differences of scores between before and after

interaction were not large as "vigorous". Moreover, scores were low in other items such as "tense", "uneasy", "lonely", and "unhappy". These scores were one or less both before and after interaction. This means that most elderly people didn't felt high tension-anxiety or depression-defection in this investigation.

As for comments and observations of nursing staffs, they were like that the elderly people were excited by interaction with Paro, and that Paro promoted conversation of the elderly people. In an interesting instance, an elderly who had seldom talked with other people, started to talk much with others when she was interacting with Paro. In addition, Paro had influences to people who were dementia. One example is that an elderly didn't try to behave independently, and often forgot things that she had just done. When she was interacting with Paro, she often laughed and she was seemed to be bright than usual. Another example is that an elderly tended to want to go back home, but she kept staying at the day service center to play with the Paro, and looked happy.

4. Analysis of Factors that Bring Effects to Elderly People

We showed that moods of elderly people were improved by interaction with Paro in the preceding chapter. Next, in order to reveal factors that influence to moods of elderly, we investigated relationship among moods of elderly, basic attributes of elderly such as age, interactions between elderly and Paro, and familiarity with Paro.

4.1. Ways of Analysis

We obtained data form 11 people who participated in the robot-assisted activity for five weeks and answered all kinds of questionnaires. Table 1 shows basic attributes of the elderly people. In order to analyze factors that bring effects to elderly, HDS-R was encoded as follows: Non-dementia = 0, Slightly degree = 1, Middle degree = 2, A little high degree = 3, High degree = 4. Moreover, experience of breeding pets was follows: I have bred pets = 1, I haven't bred pets = 0.

We investigated familiarity with Paro for once a week by questionnaires. The questionnaires have 3 items: I like the robot, I speak to the robot, and the robot is the best friend for me. These items were evaluated by five stages: 0 = not at all, 1 = a little, 2 = moderately, 3 = quite a bit, and 4 = extremely.

We recorded interaction between elderly people and Paro by a video camera all the time. However, 1st week was a trial period. We tried several positions for the camera, and decided the best position. Next, we counted number and time of touch between elderly people and Paro, and number of speech to Paro in 20 minutes interaction. Here, we are necessary to mention about definition of the number of speech and touch. In this research, we defined that one speech has an interval between the speech and next speech when the time was more than 3 sec. One touch was defined in the same way.

Table 1 Basic Attribute of 11 Subjects

Sex		All women
Age		82.7±5.9 (SD)
HDS-R	Non-dementia	6
	Slightly degree	2
	Middle degree	0
	A little high degree	2
	High degree	1
Experience of breeding pets	I have bred pets	7
	I haven't bred pets	4
Attendance days of experiment for a week	One day	5
	Two days	5
	Three days	1

Table 2 Familiarity with Paro

	2nd week	5th week
I like the robot (AV±SD)	2.0±1.6	1.9±0.8
I speak to the robot (AV±SD)	2.0±1.3	1.8±1.2
The robot is a good friend for me (AV±SD)	1.3±1.2	1.8±1.3

Next, there were differences of influences of Paro on moods of elderly people between when the elderly people were not familiar with Paro and when they were familiar. Therefore, we applied multi-regression analysis to data of 2nd week and 5th week by stepwise of regression. Dependent variables were difference of vigor scores between before and after interaction. Explaining variables were subjects' basic attributes, familiarity of Paro, interaction between subjects and Paro.

We set P values as standards that adding/removing of explaining variables from a model, as follows: adding of variables were P = 0.05, removing of variables were P = 0.10. Moreover, there were strong correlations ($r > 0.7$) between following pairs of variables. As for 2nd week, pairs of variables were: HDS-R – number of touch, time of touch – number of touch, I like the robot – number of speech, and I speak to the robot – (I like the robot, the robot is the best friend for me). As for 5th week: number of touch – number of speech, and I speak to the robot – the robot is the best friend for me. Therefore, these variables were selected alternately and added to a model.

We selected a model that had the highest multiple correlation coefficient adjusted for the degree of freedom. All above data analysis were done with SPSS10.0.7 for Windows.

4.2. Results of Analysis

Table 2 shows familiarity with Paro in the 2nd and the 5th week. Average score of a question item, "the robot is a good friend for me" increased from 1.3 to 1.8. However,

we couldn't find significant change in any average scores of items.

As for interaction between elderly people and Paro, Fig.4 shows "number of speech to Paro" and Fig.5 shows "time of touch divided by number of touch to Paro". Some people spoke to Paro more, and touched longer time in the 5th week than the 2nd week.

As for analysis of factors that bring vigor to elderly people, Table 3 shows the results. In the 2nd week, we found some explaining variables such as "age" and "time of touch divided by number of touch to Paro". On the other hand, in the 5th week, we found another explaining variables such as "experience of breeding pets", and "number of speech to Paro". Therefore, we can say that factors of vigor changed with passage of time. Especially, in the 2nd week, long "time of touch divided by number of touch to Paro" brought vigor to elderly people because its standard partial regression coefficient was positive. However in the 5th week, "experience of breeding pets" influenced vigor of elderly people instead of "time of touch divided by number of touch to Paro". This result shows that quality of interactions changed, for example small quantity of interactions brought vigor to elderly people, on the other hand, many quantity of interactions didn't bring vigor to some elderly people as much as the 2nd week. Moreover, associations of pets that she bred were increased by interaction with Paro, and these associations brought vigor to them.

We found the variable "age" in both weeks. In this research, subjects who have individuality such as often laugh and talking with surrounding people actively were high age. Therefore, we consider that age is selected as an explaining variable. Moreover, in 5th week, we found that variable "number of speech to Paro" have negative standard partial regression coefficient. People who spoke to Paro very much were more vigorous than others before interaction. Therefore, increasing of their vigor is small relatively.

5. Discussions

The investigation of effects of mental commit robots on people is still on an early stage. Nevertheless, after interaction with Paro, their scores of vigorous that was one of the questionnaires item were high during five weeks. From this result, Paro brought vigor to elderly, and preserve its effects during five weeks. In addition, Paro encouraged elderly people to communicate with people. Especially, Paro was effective to dementia.

In this research, we tried to compare the effects by the regular Paro with those by a placebo Paro that was changed its program to do repetition of 5 kinds of actions and one simple reaction against stimuli. The placebo Paro was applied to elderly people after 2 weeks from the end of 5 weeks experiment. However, because of bad health and hospitalization medical checkup of subjects, we couldn't get enough number of data. In order to verify effects of Paro more accurately, we need experiment of

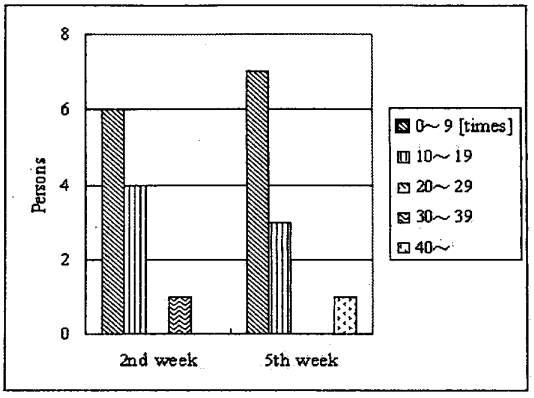

Fig.4 Number of Speech to Paro

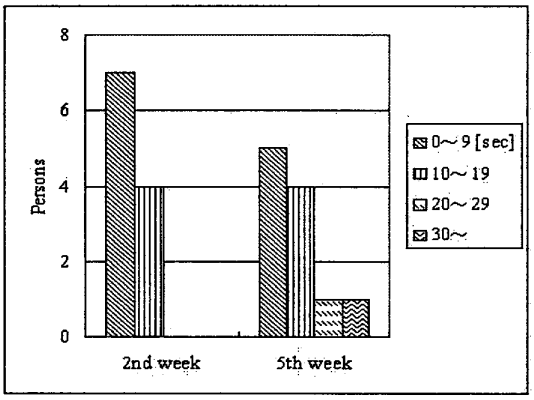

Fig.5 Time of Touch Divided by Number of Touch to Paro

Table 3 Multi-Regression Analysis

	Explaining variable	Standard partial regression coefficient	Significance
2nd week			
	Age	0.795	**
	Time of touch divided by number of touch to Paro	0.42	*
	R^2 adjusted for degree of freedom	0.739	**
5th week			
	Age	0.594	**
	Experience of breeding pets	0.454	**
	Number of speech to Paro	-0.621	**
	R^2 adjusted for degree of freedom	0.859	**

* p value < 0.05

** p value < 0.01

comparison with placebo Paro.

As for investigation of familiarity with Paro, average score of each question item didn't change for 5 weeks. Moreover, in interaction between elderly people and Paro, some people spoke to Paro more, and touched longer time in the 5th week than the 2nd week. Therefore we consider that they didn't lose interest in Paro for 5 weeks.

As for analysis of factors that bring mental effects to elderly people, we found variables such as "time of touch divided by number of touch to Paro" in 2nd week, and "experiences of breeding pets" in 5th week. These factors influenced vigor of them. We think that quantity of interaction is important at first time, however quality of interaction changed with passage of time. Because they didn't know Paro at first time and interaction with Paro were fresh stimuli for them. However they became knowledgeable about Paro through 5 weeks, and interaction with Paro became usual stimuli for them. On the other hand, some people associated their pets through interaction with Paro gradually, and they treated Paro like a real animal even though they knew Paro is a robot. Therefore, "experiences of breeding pets" brought vigor to elderly people instead of "time of touch divided by number of touch to Paro".

In this research, there are some influences such as individuality of subjects and sex because number of subjects was small and they were all women. Moreover, talking with surrounding people influenced. In order to analyze of factors that bring mental effects to elderly people more exactly, we need more number of subjects and examining interaction between one subject and a robot.

As the first experiment of robot-assisted activity for elderly people, the frequency of interaction was about 20 minutes a day and 1 to 3 days a week, and the period was for five weeks. Moreover, questionnaires concerning moods that we made were primitive. In the future, we will improve the questionnaires and carry out experiments with different frequencies and periods. In addition, we will apply Paro to different kinds of elderly institutions and do comparison with placebo Paro.

6. Conclusions

We applied Paro, a seal type mental commit robot, to robot-assisted activity for elderly people at a day service center. The experiment was carried out for six weeks in total. The results show that interaction with Paro has psychological effect and social effect to elderly people. Especially, vigor of them was brought by time of touch divided by number of touch at first, and later experiences of breeding pets.

Physiologically, We used urinary tests to find that robot-assisted activity decreased stress reaction in the elderly people [15].

We will have further experiments and research in different conditions and situations. Moreover, we will investigate relationship between functions of a mental commit robot and its effects to elderly people in robot-assisted activity.

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