Effects of Robot-Assisted Activity for Elderly People and Nurses at a Day Service Center

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Invited Paper

Mental commit robots have been developed to provide psychological, physiological, and social effects in human beings through physical interaction. The appearance of these robots is designed to emulate real animals such as a cat or a seal. The seal robot was developed especially for therapeutic applications. Seal robots have been applied to assisting the activity of the elderly at a day service center. In order to investigate the effects of seal robots on elderly people, their mood was evaluated using face scales (which express moods by identifying the appropriate facial illustration) and questionnaires. Changes in reaction to stress in the elderly was measured using urinary tests. In addition, stress of nursing staff was investigated. Their mental state was evaluated using a "burnout scale." The day service center was provided with seal robots for five weeks. As a result, the feelings of elderly people improved by the interaction with the robots. Urinary tests showed that their ability to overcome stress were also improved. Moreover, the stress levels of the nursing staff decreased because the elderly people required less supervision when interacting with the robots. Consequently, the seal robots were judged to be useful at institutions for the elderly, such as the day service center.

Keywords*—*Elderly people, human–robot interaction, mental commit robot, robot-assisted activity.

I. INTRODUCTION

A. Aged Society

According to the United Nations, the proportion of people 65 years old and over in the population of a country exceeding 7% indicates an aging society, with the proportion exceeding 14% indicating an aged society. Fig. 1 shows the changing proportions in most advanced countries. Countries other than the United States have become aged societies [1]. Such percentages are expected to increase, together with the number of elderly people who require nursing due to dementia, becoming bedridden, etc., together with the number being institutionalized for long periods in care facilities for the elderly. Moreover, the nursing staff's bodily and mental stress occasioned by manpower shortages and increasing work loads is becoming a big problem. Especially, mental stress in nursing causes Burnout syndrome [2]. It makes the nursing staff irritable, with loss of sympathy for patients. Thus, it is important to improve the quality of life (QOL) of elderly people, as this helps them to have healthy and independent lives. It also saves the social costs of elderly people.

B. Animal-Assisted Therapy and Activity

Interaction with animals has long been known to be emotionally beneficial to people. In recent years, the effects of animals on humans have been researched and proved scientifically. Friedmann investigated the one-year survival of patients were who discharged from a coronary care unit, finding that survival among those who kept pets was higher than those who did not [3]. Baum *et al.* reported that blood pressure dropped when people petted their dogs [4]. Garrity *et al.* studied elderly people who were socially isolated and lost their partner within the previous year and found that the depth of depression among those who had no pets was higher than those who did [5]. Dan *et al.* investigated the influences of pet owning on elderly people by telephone interviews. He revealed mortality and attrition were higher for former owners than current owners [6]. Lynette studied the social influences of animals on people. He found that the number of friendly approaches by strangers to people with dogs were greater than to people without dogs [7].

In medical applications, especially in the United States, animal-assisted therapy (AAT) and animal-assisted activities (AAA) are becoming widely used in hospitals and nursing homes. AAT has clear goals set out in therapy programs designed by doctors, nurses, or social workers, in cooperation

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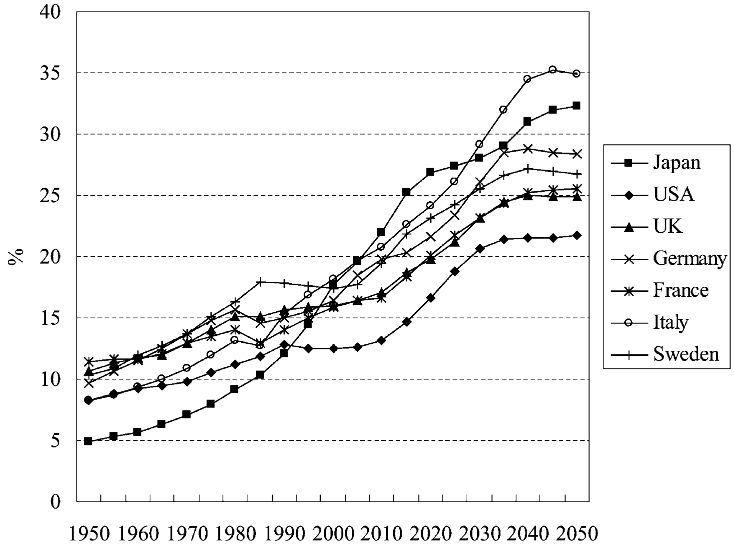

Fig. 1. Ratio of people 65 years old and over to the total population of the most advanced countries.

with volunteers. In contrast, AAA refers to patients interacting with animals without particular therapeutic goals, and depends on volunteers. AAT and AAA are expected to have three effects:

1) psychological effect (e.g., relaxation, motivation);
2) physiological effect (e.g., improvement of vital signs);
3) social effect (e.g., stimulation of communication among inpatients and caregivers).

For example, a hospitalized child who was in significant pain because of his disease was afraid to get up and walk around. However, when he was asked to take a therapy dog for a walk, he immediately agreed and walked off happily, as if all his pain diminished. Moreover, the dog acted as a medium for interaction between him and the other children [8]. In another case, a boy who, as a fetus, was exposed to crack cocaine could not speak and walk. However, through interaction with therapy dogs and birds, he improved both his linguistic and motor ability [9].

As for people with AIDS, it is important to reduce their stress because there is a strong relationship between the complications of stress and immune deficiency. AAT brings the effects of relaxation to them and helps them to stay connected with the world [10].

In addition to these effects, AAT and AAA at nursing homes provides the effects of rehabilitation to elderly people and offers laughter and enjoyment to a patient who has little remaining life [11]. Moreover, there are some cases where the therapy has improved the state of elderly people with dementia.

However, most hospitals and nursing homes, especially in Japan, do not accept animals, even though they admit the positive effects of AAT and AAA. They are afraid of negative effects of animals on human beings, such as allergy, infection, bites, and scratches.

C. Mental Commit Robot

Science and technology are developed on the basis of objectivity, and this development has been designed for universality and commonness. "Technology," as an application of the practice of science, is the skill of modifying and processing events in nature so that they become useful to human life. Science, which is the foundation of technology, is a body of knowledge which is systematic and empirically verifiable.

On the other hand, "art" is the activity and asset of humans who attempt to create and express aesthetic value by making full use of certain materials, techniques, and methods. It is the industrial arts that create practical objects with aesthetic value.

Robotics has been applied to automation in industrial manufacturing. Most robots are machines for optimizing a practical system in terms of objective measures such as accuracy, speed, and cost [12]. Therefore, humans give machines suitable methods, purposes, and goals [13], [14]. Machines are the passive tools of humans.

We have been researching robots in contrast to such machines. If a robot were able to generate its motivation and behave voluntarily, it would have significant influence over an interacting human. At the same time, the robot would not be a simple tool for the human nor could it be evaluated only in terms of objective measures. We have been designing animal-type robots as examples of artificial emotional creatures [15]–[29]. The animal-type robots have physical bodies and exhibit active behavior while generating goals and motivations by themselves. They interact with human beings physically. People recognize the robots and subjectively interpret their movement based on their knowledge and experience. When we engage physically with an animal-type robot, it stimulates our affection. We then experience positive emotions such as happiness and love, or negative emotions such as anger and fear. Through physical interaction, we develop an attachment to the animal-type robot, while regarding it as either intelligent or stupid from our subjective measures. In this research, animal-type robots that give mental value to human beings are referred to as mental commit robots. Three examples that we have developed are dog, cat, and seal robots.

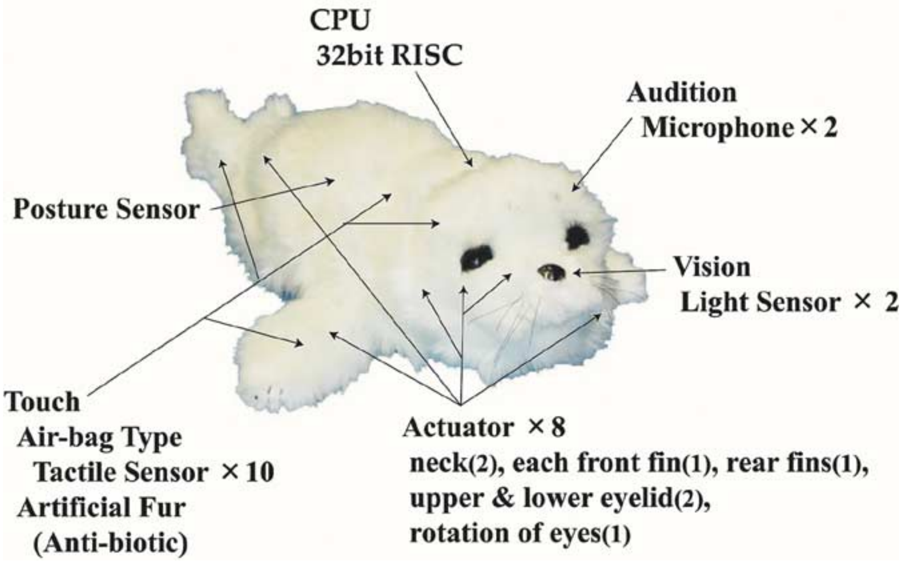

Fig. 2. Seal robot Paro.

Fig. 3. Interaction between inpatient and seal robot, and social interaction between children.

D. Robot-Assisted Therapy and Activity

We have proposed robot therapy [15]. We have used a seal robot named Paro (Fig. 2), instead of real animals, in pediatric therapy at a university hospital [23], [24], termed robot-assisted therapy (RAT). The children's ages were from 2 to 15 years, some of them having immunity problems. Paro was given to them three times a day for 11 days. The children's moods improved on interaction with Paro, encouraging the children to communicate with each other and caregivers (Fig. 3). In one striking instance, a young autistic patient recovered his appetite and his speech abilities during the weeks when Paro was at the hospital. In another case, Fig. 4 shows interaction between Paro and a long-term inpatient. She felt pain when she moved her body, arms, and legs and could not move from her bed. However, when Paro was given to her, she smiled and was willing to stroke Paro. A nurse said that Paro had a rehabilitative function as well as a mental effect.

Fig. 4. Interaction between child inpatient on bed and seal robot.

Other animal-type robots (such as Furby, AIBO [30], NeCoRo, etc.) have been released by several companies. Then robot-assisted activity that uses those robots has been tried. For example, Yokoyama used AIBO in a pediatrics ward and observed the interaction between children and AIBO [31]. He pointed out that the stimulus received from AIBO was strong; however, the stability was quite weak, compared with living animals. In other words, when people meet AIBO for the first time, they are interested in it for a while. However, relaxation effects such as those obtained from petting a real dog are never felt from AIBO.

In this paper, we discuss the application of the seal robots to assist elderly people at a day service center, observing their psychological and social effects. Urinary tests were conducted to establish the physiological effects,. Here, space limitations prevent full discussion of the results. However, details are described in [27]. Moreover, we discuss the influences to mental impoverishment of nursing staff.

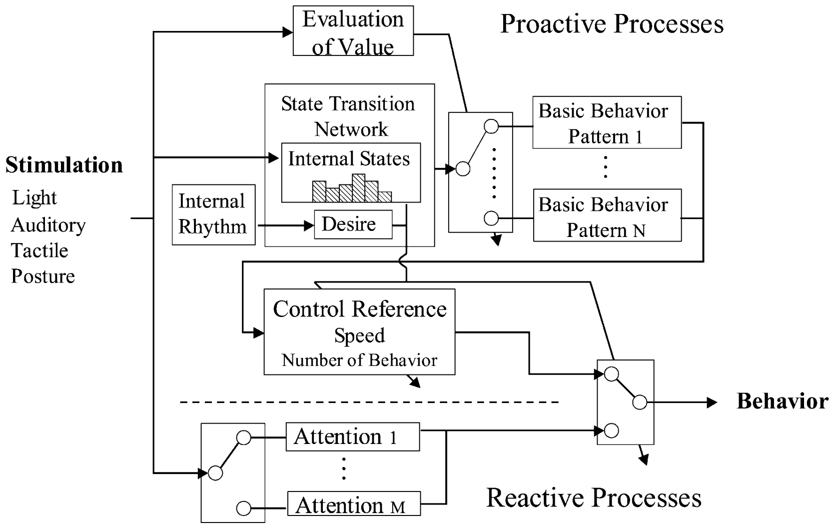

Fig. 5. Behavioral generation system of Paro.

Section II describes a seal robot that was used for robot-assisted activity (RAA). Section III describes ways of experiments and explains the effects of RAA on elderly people. Section IV explains the effects of RAA on nursing staff. Section V discusses current results of RAA and future works. Finally, Section VI offers conclusions.

II. Specifications of the Seal Robot

The seal robot Paro was developed to physically interact with human beings (Fig. 2). Paro's appearance is that of a baby harp seal, which has white fur for three weeks after birth. As for perception, Paro has tactile, vision, auditory, and posture sensors beneath its soft white artificial fur. In order that Paro should have a soft body, an air-bag-type tactile sensor was developed and implemented. To provide movement, the robot has eight actuators; two for upper and lower eyelids, one for rotation of eyes, two for the neck, one for each front fin, and one for two rear fins. Paro weighs about 2.8 kg.

Paro has a behavior-generation system consisting of two hierarchical layers of processes: proactive and reactive (Fig. 5). These two layers generate three types of behavior: proactive, reactive, and physiological behaviors.

A. Proactive Behavior

Paro has two layers to generate its proactive behavior: a behavior-planning layer and a behavior-generation layer. By addressing its internal states of stimuli, desires, and a rhythm, Paro generates proactive behavior.

1) Behavior-Planning Layer: This has a state transition network based on the internal states of Paro and Paro's desire, produced by its internal rhythm. Paro has internal states that can be named with words indicating emotions. Each state has a numerical level which is changed by stimulation. The state also decays in time. Interaction changes the internal states and creates the character of Paro. The behavior-planning layer sends basic behavioral patterns to behavior-generation layer. The basic behavioral patterns include several poses and movements. Here, although the term "proactive" is used, the proactive behavior is very primitive compared with that of human beings. We implemented behavior in Paro similar to that of a real seal.

2) Behavior-Generation Layer: This layer generates control references for each actuator to perform the determined behavior. The control reference depends on magnitude of the internal states and their variation. For example, parameters can change the speed of movement and the number of instances of the same behavior. Therefore, although the number of basic patterns is finite, the number of emerging behaviors is infinite because of the varying number of parameters. This creates lifelike behavior. In addition, to gain attention, the behavior-generation layer adjusts parameters of priority of reactive behaviors and proactive behaviors based on the magnitude of the internal states. This function contributes to the behavioral situation of Paro, and makes it difficult for a subject to predict Paro's action.

3) Long-Term Memory: Paro has a function of reinforcement learning. It has positive value on preferred stimulation such as stroking. It also has negative value on undesired stimulation such as beating. Paro assigns values to the relationship between stimulation and behavior. Gradually, Paro can be tuned to preferred behaviors of its owner.

B. Reactive Behavior

Paro reacts to sudden stimulation. For example, when it hears a sudden loud sound, Paro pays attention to it and looks in the direction of the sound. There are several patterns of combination of stimulation and reaction. These patterns are assumed as conditioned and unconscious behavior.

C. Physiological Behavior

Paro has a diurnal rhythm. It has several spontaneous needs, such as sleep, based on this rhythm.

III. Robot-Assisted Activity for Elderly People

We applied Paro to RAA for elderly people at a day service center in order to investigate its effects on the elderly. The day service center is an institution that aims to decrease nursing

Fig. 6. Scene of usual activity of elderly people at a day service center.

Fig. 7. Interaction between elderly people and seal robot.

load for a family by keeping elderly people during the daytime (9:00–15:30). Services such as bathing, massage, physical exercise, and games are provided to the elderly people there. Fig. 6 shows activity of the elderly people. They communicated little and the atmosphere was gloomy.

Before starting the RAA, we explained the purposes and procedure to the elderly people and received their approval.

Some people could not be questioned (no answer to questionnaires, bedridden, etc). So we questioned the nursing staff, who knew the elderly people well, to determine who would participate. Twenty-three subjects were finally chosen. All of them were women, aged between 73 and 93 years old. Several subjects presented dementia, in which case, the nursing staff judged the dementia level of each subject in terms of the revised Hasegawa's dementia scale (HDS-R). Their dementia levels were as follows:

1) nondementia: 15 people;
2) slight degree: three people;
3) slightly high degree: three people;
4) high degree: two people.

A. *Method of Interaction*

Paro was given to the elderly people at the day service center three days per week for five weeks. They interacted with Paro from one to three days a week, because they did not attend the center every day. We prepared a desk for Paro in the center of the table, and up to eight people were arranged as shown in Fig. 7. If there were more than eight persons, they were divided randomly into two groups. First one and then the other group interacted with Paro for about 20 min at a time. When the number of people was small, they could interact with Paro for about 40 min, if they wished.

B. *Methods of Evaluation*

In order to investigate the effects on the elderly people before and after interaction with Paro, the following three types of data and additional information were collected:

1) face scale [32] (Fig. 8);
2) questionnaires concerning moods;
3) urinary tests [35]–[37];
4) comments of nursing staff.

The face scale contains 20 drawings of a single face, arranged in serial order by rows, with each face depicting a slightly different mood state. A graphic artist was consulted so that the faces would be portrayed as genderless and multiethnic. Subtle changes in the eyes, eyebrows, and mouth were used to represent slightly different levels of mood. They are arranged in decreasing order of mood and numbered from 1 to 20, with 1 representing the most positive mood and 20 representing the most negative mood. As the examiner pointed at the faces, the following instructions were given to each subject: "The faces below range from very happy at the top to very sad at the bottom. Check the face which best shows the way you feel inside now."

The Profile of Mood States (POMS) is a popular questionnaire which measures a person's moods [33]. POMS is used in various research fields such as medical therapy and psychotherapy. However, it is time- consuming to answer questionnaires, because there are so 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 devised questionnaires that consisted of six items extracted from POMS. We selected two items that have a high significance for each of three factors of POMS: tension–anxiety, depression–dejection, and vigor. The selected items were shown in Table 1. These items were evaluated in five stages of 0–4 as used in POMS: $0 = \text{not at all}$, $1 = \text{a little}$, $2 = \text{moderately}$, $3 = \text{quite a bit}$, and $4 = \text{extremely}$.

C. *Results of Evaluation*

The face scale and questionnaires concerning moods were submitted to the elderly people, before and after interaction with Paro. In order to examine their moods after Paro had gone, they were also interrogated in the sixth week of the experiment, when Paro was withdrawn.

Regarding the face scale, we obtained data from 12 people (Table 2). Fig. 9 indicates the average face value (low score—positive mood; high score—negative mood). Average scores before interaction varied from about 5.3 to 3.0. However, scores after interaction were constant at about 3.0 for five weeks. Moreover, the sixth week, when Paro had been removed, was higher than the score after interaction with Paro.

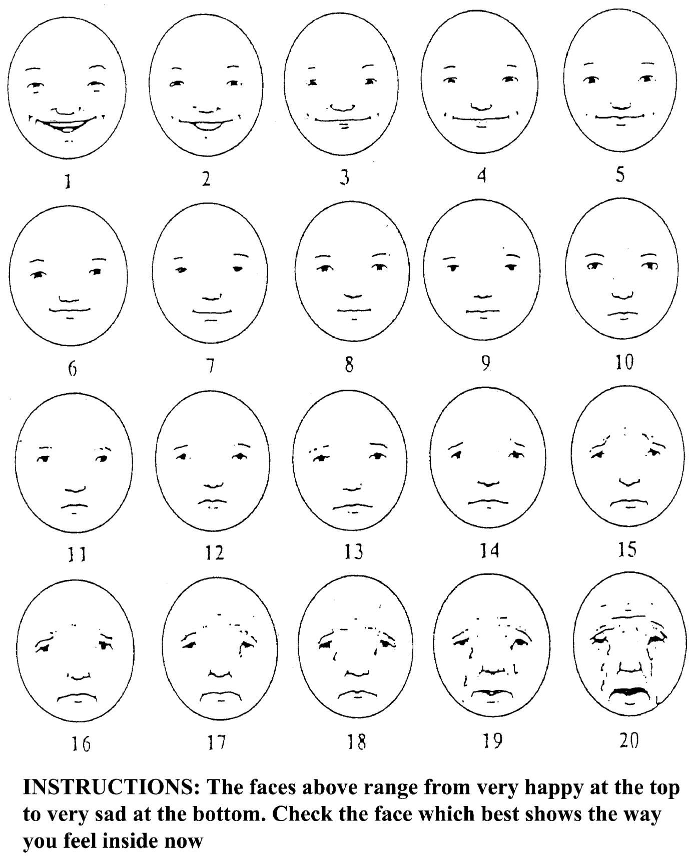

Fig. 8. Face scale.

Table 1
Questionnaires Concerning Moods

Questionnaire items
1. Tense
2. Vigorous
3. Lonely
4. Uneasy
5. Full of pep
6. Unhappy

Table 2
Basic Attribute of 12 Subjects

Sex		All women
Age (ave. ± sd)		83.6 ± 6.3
HDS-R	*Non-dementia*	7
(Number of people)	*Slightly degree*	2
	A little high degree	2
	High degree	1
		N = 12

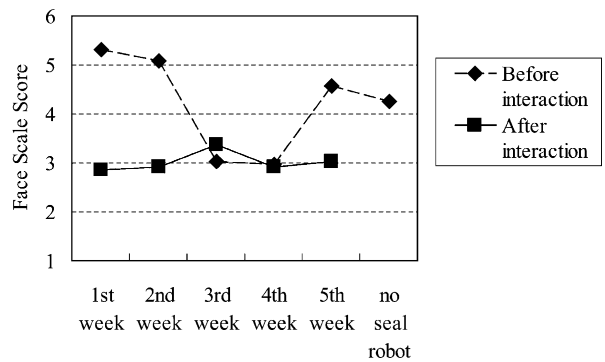

Fig. 9. Results of average face scale scores of 12 elderly people over six weeks.

Table 3
Basic Attribute of 11 Subjects

Sex		All women
Age (ave. ± sd)		82.7 ± 5.9
HDS-R	*Non-dementia*	6
(Number of people)	*Slightly degree*	2
	A little high degree	2
	High degree	1
		N = 11

Thus, interaction with Paro improved the mood state of the subjects, and its effect was unchanged throughout during the five weeks of interaction.

Regarding questionnaires concerning moods, we obtained data from 11 people (Table 3). Fig. 10 shows the average result of the question item "vigorous." A high score in this item expressed that people felt strong in their moods. The scores after interaction increased from about 1.4 to 2.0. However, these scores were higher than those preceding interaction after the second week. As a statistical analysis, we applied Wilcoxson's sign rank sum test [38] to the scores before and after interaction for each week. As a result, significant

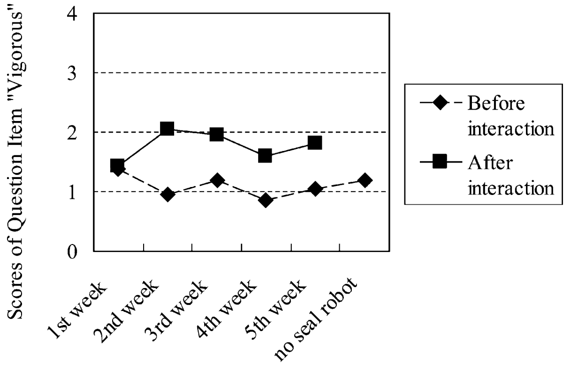

Fig. 10. Average scores of the question item "vigorous" by 11 elderly people for six weeks.

changes were seen in the second, third, fourth, and fifth weeks ($p < 0.05$). Moreover, the score of the sixth week, when Paro had been withheld, was lower than the scores after interaction with Paro in the previous weeks. Therefore, Paro brought "vigor" to elderly people through the interaction, and its effect was maintained for five weeks. Regarding the item "full of pep," differences in scores 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 lower, both before and after interaction. This means that most elderly people did not feel high tension–anxiety or depression–defection in this investigation.

Regarding urinary tests, we explain the results briefly. We examined the change in stress reaction of elderly by measuring urine 17–Ketosteroid sulfates (17-KS-S) and 17-hydroxycorticosteroids (17-OHCS) values before and after the introduction of Paro. The 17-KS-S value, indicating the restorative degree to the stress, has a high value in healthy individuals [35]. The 17-OHCS value, indicating the stress load degree, rises at the stress [36], [37], and the ratio of 17-KS-S/17-OHCS indicates an inclusive living organisms reaction [37]. The participant's 17-KS-S values and ratios of 17-KS-S/17-OHCS were increased after introduction of Paro. Therefore, we consider that RAA improved the ability to in the elderly to recover from stress. More details are described in [27].

Regarding the comments and observations of the nursing staff, interaction with Paro made the elderly people more active and communicative, both with each other and nursing staff (Fig. 7). In an interesting instance, an elderly woman who rarely talked with others began communicating after interacting with Paro. In addition, Paro had an influence on people with dementia. A woman who had refused to help herself and was frequently forgetful often laughed and became brighter than usual after playing with Paro. Another elderly woman who had previously wanted to go back home soon kept staying at the day service center to play with Paro and looked happy.

IV. Influence on Mental Impoverishment of Nursing Staff

In the preceding section, we showed that moods of elderly people were improved by interaction with Paro. We thought that improving of their moods would reduce nursing loads and that the nursing staff's mental stress would decrease. Thus, we investigated the mental impoverishment of nursing staff.

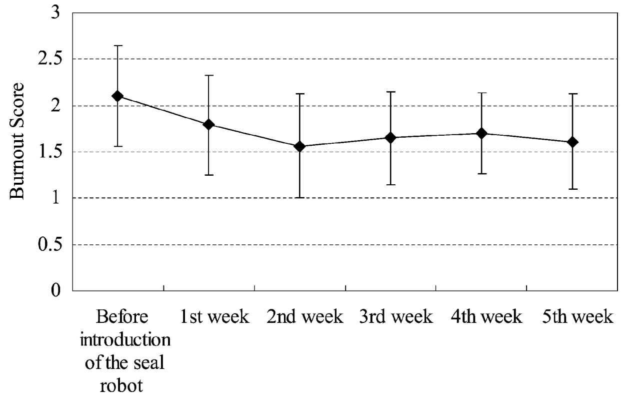

Fig. 11. Average burnout score of the six nursing staff members for six weeks.

Six nursing staff members who worked at the day service center were investigated. Two were men. Their tasks included providing elderly people with services such as bathing, physical exercise, games, etc. They had worked at the center from one to four years.

A. Method of Evaluation

We used the burnout scale to investigate mental impoverishment of the nursing staff [34]. Burnout is a syndrome where nurses lose all concern or emotional feelings for the persons they work with and come to treat them in detached or even dehumanized manner. This occurs in nurses who have to care for too many people with continual emotional stress [2]. The burnout scale is a questionnaire that consists of 21 items. These items represent three factors such as body, emotions, and mental impoverishment. Each item is evaluated over seven stages. If total average score of the items is 2.9 or less, people are mentally and physically healthy and mentally stable. If the score is 3.0–3.9, the symptoms of burnout are present. People are judged to fall into the burnout category if the score is 4.0 or more.

B. Results of Evaluation

We distributed the burnout scale to nursing staff once per week for six weeks, from a week before introduction of Paro to the last week. Fig. 11 shows the average burnout score of the nursing staff. All of the scores of nursing staff were smaller than 2.9. No nursing staff had symptom of burnout in this investigation. The average burnout score of a week before introduction of Paro was the highest, and then the average score decreased until second week of after the introduction, and kept the small score until the last week. As a statistical analysis, we applied Friedman's test [39] to the burnout score. We obtained statistically significant changes that the score decreased ($p < 0.05$). As a result, mental impoverishment of the nursing staff decreased through RAA.

V. Discussions

The investigation of effects of mental commit robots on people is still at an early stage. Nevertheless, after interaction with Paro, the face scale scores of elderly people were good, and their vigor scores in the questionnaires were high, confirming that Paro improved the mood of elderly people and made them more vigorous. In addition, Paro encouraged elderly people to communicate, both with each other and nursing stuff. Moreover, Paro was effective for people with dementia.

Physiologically, urinary tests showed that the ability to recover from stress was improved in the elderly. The details are described in [27].

In this research, we compared the effects of the regular Paro with those of another Paro with a program modified to repeat five types of action and one simple reaction against stimuli. The reprogrammed Paro was offered to elderly people two weeks after the end of the five-week experiment. However, because of bad health and hospitalization medical checkup of the subjects, we were unable to obtain sufficient data. In order to verify effects of Paro more accurately, and to investigate relationship between functions of Paro and its effects, we need experimental comparison with the reprogrammed Paro.

Regarding the nursing staff, their burnout scores decreased after introducing Paro to the elderly people. We consider that improvement of elderly people's moods reduced their dependency on nurses, and nursing staff's mental impoverishment decreased. As a result, Paro is useful at elderly institutions such as day care centers.

In this initial experiment of RAA for elderly people, the frequency of interaction was about 20 min a day, for one to three days a week, over a period of five weeks. Moreover, questionnaires concerning the mood of the subjects were primitive. In the future, we will improve the questionnaires and carry out experiments with different frequencies and periods of interaction. In addition, we will apply Paro to different types of institutions for the elderly and make comparisons with the reprogrammed Paro.

VI. Conclusion

We applied a mental commit robot, Paro, to RAA 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, physiological, and social effects on elderly people. In addition, the RAA reduces mental impoverishment, known as burnout, of nursing staff giving care to elderly people.

Following this experiment, we applied Paro to RAA for the elderly who stayed at a health service facility for the aged. Similar effects of Paro were found [28], [29].

We intend to conduct further experiments and research in different conditions and situations. Moreover, we will investigate the relationship between the functions of a mental commit robot and its effects on elderly people in RAA.

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