# Trial of Robot-Assisted Rehabilitation Using Robotic Pet

M. Naganuma, T. Tetsui, E. Ohkubo, R. Kimura, N. Kato, and S. Sato

***Abstract*— Trial studies of the application of the robotic dog AIBO to rehabilitation are ongoing at several hospitals and geriatric nursing homes. In this study, noninvasive measurement methods such as motion tracking on a video recorder are adopted for evaluating the effectiveness of robot-assisted rehabilitation in terms of mental, social and physical aspects. A comparison between therapy using an autonomous robot and a remote controlled robot showed that the latter was more effective in assisting rehabilitation in the climate of today's robotic technology. A simple and easy-to-use controller was developed for the therapist to use with the remote controlled robot. For the simplest type of technology, a controller with a hand motion sensing capability was assembled and tested with aged women for an in-house walking program.**

## I. Introduction

Most industrially developed countries are now seeing the emergence of an unprecedented super-aging society. In Japan, since the dramatic revision of the medical insurance system was introduced to reduce medical expenses, there have been various serious effects on the care and/or medicine provided to geriatric persons, such as cuts in the number of staff and reductions in hospital days. One of the solutions to address these issues is the use of robots as human pets and other related information communication technologies. The key issues to address are the mental, social and physical care of geriatric persons. Although robotic technologies have been successfully used in the physical care, application to the mental and social care is still under study. The pioneering works suggested that commercially available robotic pet is one of the candidates for this purpose [1-4] while the huggable robotic pets were specially designed and developed for therapy use [5-6]. Animal-assisted activity or therapy (AAA/AAT) is well known to be effective for healing and improving the quality of life of geriatric persons in hospitals or the elderly in nursing homes[7]. However, there are some difficulties associated with the use of living animals, such as allergic reactions and the spread of unwanted bacteria. Moreover, there is a need for well-trained handlers to prevent accidents like sudden bites. Feeding and excretion also necessitates human assistance. In this regard, a robotic pet instead of a living animal can be used to overcome such difficulties. Although the healing capability of a robotic pet is insufficient when compared with that of a living animal [8], it is still an attractive alternative because it can be integrated with communication networks such as the Internet. Odetti at al. used programmed robotic pet and analyzed the interactive effects on the patients with dementia[9]. This paper describes the results of preliminary studies of robot-assisted activity and therapy at an elderly ward of a hospital and in geriatric nursing homes using Sony's AIBO as a robotic pet.

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M. Naganuma, T. Tetsui, E. Ohkubo, and R. Kimura are with Teikyo University of Science and Technology, Uenohara, Yamanashi Pref., 409-0193 Japan (phone: +81-554-63-4411; fax: +81-554-63-4431; e-mail: naganuma@ ntu.ac.jp)

N. Kato is with Tokorozawa Loyal Hospital, Tokorozawa, Saitama Pref., 359-1152 Japan

S. Sato is with Kofu Municipal Hospital, Kofu, Yamanashi Pref., 400-8585 Japan

## II. General Experimental Condition

Robot-assisted therapy (RAT) is typically carried out under the supervision of a medical doctor or nurse, and has clear evaluation goals. On the other hand, robot-assisted activity (RAA) is usually performed to please geriatric persons, that is, to simply create a feeling of fun and happiness. Robot-assisted rehabilitation is considered to be one aspect of RAT. Because a robotic pet with advanced artificial intelligence (AI) is still incapable of autonomous behavior and cannot provide an accurate response to a geriatric person, an intervener coordinates the activity of the robot and the elderly person during rehabilitation. The typical configurational arrangements for carrying out RAA or RAT are shown in Fig. 1. Figure 1(a) shows the relationship of a pet owner with his/her own pet living together at home; Figures 1(b) and (e) show typical cases of the relationship between an elderly person, a robot and an intervener, which are also shown in Figs. 2 and 3, respectively. In the case of play therapy for a child with Asperger's syndrome, the configuration indicated in Fig. 1(c) was used, in which the patient reflected on the human relationships of herself and her sisters with multiple robotic pets and was helped objectively to understand the situation [10]. In the case of Fig. 1(d), we attempted to generate communication between 2 patients using one robot as a common attention-drawer.

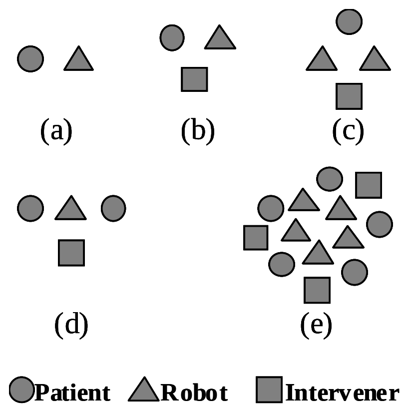


**Fig.1 Relationship between patient, robot and intervener**

**Fig.2 Configuration of remote operation**

**Fig.3 Typical arrangement of group RAA/RAT**

In our RAA and RAT, we used several kinds of commercially available entertainment robots such as the robotic dog "AIBO" (Sony), the robotic cat "NeCoRo" (OMRON), and the robotic seal "Paro" (AIST), as well as electrically driven stuffed toys were used [11]. Of these robots, AIBO was selected for this study because it can be programmed by the user and is equipped with a wireless local-area network (LAN) system.

RAA/RAT was conducted in the geriatric ward of a general hospital of 300–400 bed capacity and at geriatric nursing homes with 100 habitants. Subjects ranged in age from their 60s to 90s and some had brain problems such as cerebral hemorrhage or dementia.

AIBO can perform simple motions or combinations when programmed in advance or by using a real-time remote control through a wireless LAN system. Some examples of these motions are sitting, standing, raising a limb, turning the face, head nodding, vocalization of short words, and hearing motions. In Fig. 2, the person on the right hand side is the remote control operator of AIBO and the subject is on the wheel chair beside a therapist. The robot operator positions himself behind the subject so as not to disturb the subject and to allow the therapist to make eye contact with him. In the case of group RAA (Fig. 3), pre-programmed robots were used. The duration of interaction with AIBO was typically 30 min.

An important point of note is that the condition of the subject should be measured noninvasively. In this study, the motion tracking of one part of the body, the eye contact of the subject [12], and the galvanic skin reflex (GSR) were all evaluated during an activity, in addition to the measurements of blood pressure, heartbeat, and body temperature before and after the activity.

## III. Results and Discussion

### A. Evaluation of Blood Pressure

Blood pressure was measured just before and after an activity with a therapist, and the results for 10 cases of 7 subjects are shown in Fig. 4. The average diastolic blood pressure was reduced by 9.9 mmHg (12%), which appeared to be a meaningful reduction, while the average systolic blood pressure was reduced by 2.4 mmHg. From these results, two possible processes may underlie the reduction in blood pressure. One is purely by mental process and the other is through physical exercise, as stimulated and guided by the robot's action.

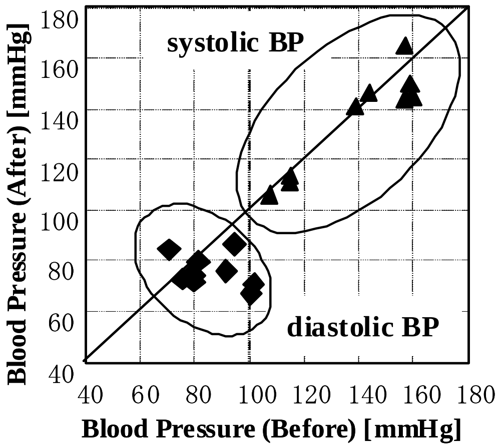


**Fig. 4 Blood pressure before and after activity**

### B. Evaluation of Galvanic Skin Reflex

The GSR signal is used to evaluate the wakefulness of a subject. In this study, 2 small electrodes were placed on the subject's fingers of one hand and temporal changes in electronic conduction on the skin were measured. In this measurement, the conductivity reflects the wakefulness of the subjects through sweating. The GSR signals of 7 subjects different from the subjects shown in Fig. 4 were measured during a rehabilitation session and are summarized in Table 1. All the subjects suffered from some kind of brain disease and their score on Hasegawa's Dementia Scale-Revised (HDSR) was from 16 down to 0. The rehabilitation program was composed of 3 parts, randomly ordered, that is, conventional rehabilitation with small props, rehabilitation with an autonomous robotic pet, and rehabilitation with a remote controlled robotic pet. Autonomous behavior was produced by "Oriko AIBO" software (Sony Corp.). In the case with a remote controlled robot, 5 of 7 (70%) subjects with sympathicotonia showed improvement in wakefulness. On the other hand, in the case with an autonomous robot, only 1 subject with sympathicotonia and 2 subjects with parasympathicotonia showed deterioration in wakefulness. Sympathicotonia was observed in all the subjects in the control group comprising 3 healthy women with an average age of 60. The outcome of the conventional rehabilitation was similar to that in the case of using a remote controlled robot, showing that the robot was effective to some extent relative to the conventional program. Interestingly, the subjects showed a more positive

Table 1 Summary of GSR measurement

| subject | disease | age | HDSR | conventional | autonomous | remote |
|---|---|---|---|---|---|---|
| A | cerebral infarct | 78 | 0 | S | NC | S |
| B | thalamus cerebellar hemorrhage | 87 | 5 | S | NC | S |
| C | thalamus hemorrhage | 87 | 6 | NC | NC | NC |
| D | thalamus hemorrhage | 76 | 7 | S | P | S |
| E | acute subdural | 79 | 8 | NC | NC | NC |
| F | cerebral hemorrhage | 76 | 10 | S | P | S |
| G | thalamus hemorrhage | 72 | 16 | S | S | S |
| H | control (no disorder) | 60' | - | S | S | S |
| I | control (no disorder) | 60' | - | S | S | S |
| J | control (no disorder) | 60' | - | S | S | S |

S : sympathicotonia P : parasympathicotonia
NC : no change

attitude to rehabilitation exercise when a robot was used than when conventional tools were employed. This is because the robotic pet stimulated the subjects, resulting in a meaningful action by making them recall a living pet to mind. In the present technical state, it was shown, in contrast, that the autonomous robot does not react in a timely manner with the subject. It also fails to understand the given instructions and is thus insufficient for improving the subject's level of wakefulness. Nevertheless, further progress in AI research will pave the way for the effective application of autonomous robots to rehabilitation.

### *C. Robot As a Gaze Target*

Since a robotic pet is some kind of stranger in the daily life of a subject, it can serve as a strong gaze target. This principle was applied to a subject suffering from unilateral spatial agnosia to improve his spatial recognition ability. Figure 5 compares the trajectory of the head movement of the subject during rehabilitation with and without a remote controlled robot. An infrared video movie of the subject with special marker balls on the forehead and tip of the nose was taken during a rehabilitation exercise. The movement of the subject's head was analyzed using motion tracking software following the marker balls and the resultant trajectories were overlayed on the last frames of the analyzed movie, which are shown in Fig. 5. The top and bottom panels correspond to the rehabilitation using conventional instruments and AIBO, respectively. In the case of the rehabilitation without a robot (Fig. 5; top), an occupational therapist instructed the subject to transfer a small prop from his left side where he has intact recognition to his right side with spatial agnosia. In the case of rehabilitation with a robot (Fig. 5; bottom), AIBO was

**Fig.5 Motion tracks of patient's head.**
**Top: conventional exercise**
**Bottom: exercise with remote controlled robot**

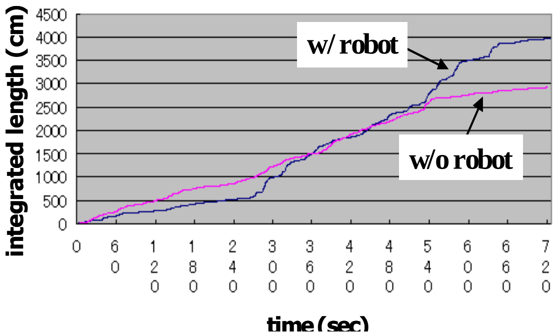


**Fig.6 Integrated movements of patient's forehead**

controlled remotely and made to guide the consciousness of the subject from the left side to the right side. AIBO sends stimuli to a subject by raising the forelimb, shaking the head, or barking on the left side of the subject and then moving to the right side to keep the subject's attention. As can be clearly seen in the figure, AIBO succeeded in guiding the movement of the subject's head to the right side, implying that the consciousness of the subject was guided more easily than in the case of a simple transfer exercise. Both trajectories were integrated with time and are compared in Fig. 6. Total movement during a 12-min exercise with AIBO reached up to 4 m, which was a 30% increase over the case of conventional exercise.

Importantly, helping long-stay residents of nursing homes avoid solitude is also one of the issues that need to be addressed in these settings. Therefore, the remote controlled robotic pet was also used in this study in a trial attempting to create a relationship of mutual reliance. This trial is a form of play therapy in which AIBO was co-owned and placed between 2 subjects, as shown in Fig. 7 [13]. The

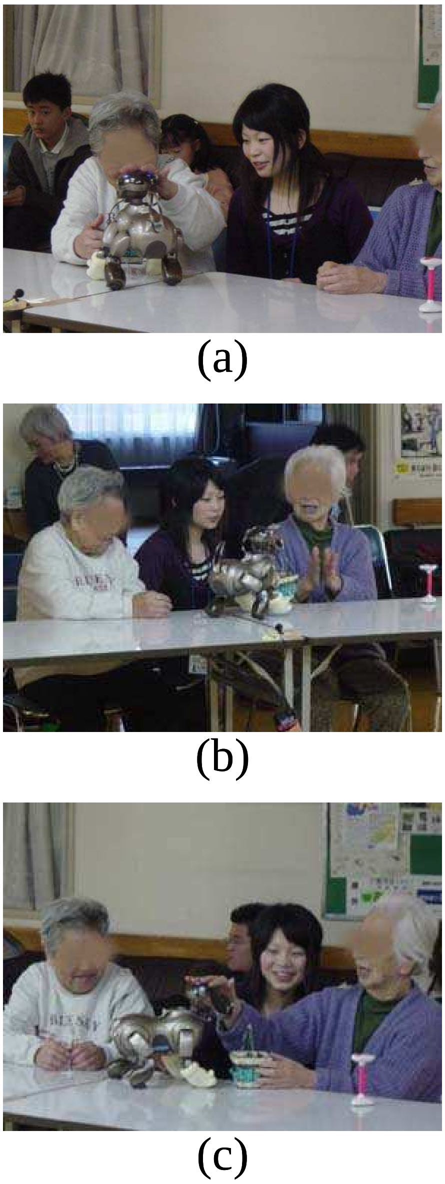


**Fig.7 Establishment of a field of communication using remote controlled robot**

subjects aged over 70 suffered from senile dementia. They were sat side by side near the table edge and in this configuration they were not able to look at each other. In order to create mutual concern, a small item such as a quoits ring or a basket was used. The series of motion shown in Fig. 7 was constructed based on a specific scenario. The subject on the left side tried to place the basket in AIBO's mouth (Fig. 7(a)). The operator controlled AIBO and made its mouth open in synchrony with the subject's action. Then, AIBO carried the basket to the other subject and was greeted with applause (Fig. 7(b)). Finally, the subject on the right side received the basket and praised AIBO by stroking its head, with the sender watching this situation with great interest (Fig. 7(c)). After this activity, the sender and receiver exchanged roles and preformed the same activity in a similar manner. The intervener supervised the subjects to help them follow the scenario. Although the effect of this activity was not immediately clear and direct, it is expected that repeating this scenario would bring about a field of communication and also create some kind of relationship between the 2 subjects.

## IV. USER FRIENDLY CONTROL OF ROBOT

In this study, a remote controlled robot was found to be effective in aiding rehabilitation compared with the existing insufficient AI technology, as shown above. However, a robot operator as well as a therapist or an intervener is needed in such form of therapy. Moreover, the shortage of caregivers can also be problematic in providing therapy. To address these issues, we developed a simple handheld operation console instead of the console on a personal computer in order that the therapist could take direct control of the robot during the rehabilitation therapy.

### *A. Control of Operation Console by Therapist*

The operation console software of AIBO is supplied with the robot by the vendor, with the product names of AIBO Navigator 2 and AIBO Entertainment Player. Since the manufacturing concept of these products is for entertainment use, they are somewhat redundant and it takes time for them to be used effectively, whereas the elemental motions needed for rehabilitation are much more limited. A schematic of the developed remote control system for therapists is shown in Fig. 8. Fifty-two motions were categorized into 7 groups corresponding to the 7 pages of a Web style console with a touch screen command input, as shown in the topmost part of Fig. 8. Touching the commands twice using a pen or finger allowed us to send a command to AIBO. The system is sever-less and


**Fig.8 Remote control system developed for use by the therapist**

commands are directly sent to AIBO. Moreover a categorized simple log of the subject can be recorded by a single click simultaneously with the sending of a command. Preliminary results using this system at 3 geriatric nursing homes are shown in Fig. 9. The results were divided into 3 simple categories: 1) the subject moved physically in response to AIBO, 2) the subject remained still but showed a pleasant reaction, and 3) the subject showed no reaction. From these results, it can be inferred that the activity level of a subject clearly depends on the average degree of care of the subjects approved by the public office. The activity levels ranged from 1 (lightest) to 5 (heaviest), and an increase in the degree of care by 0.9 resulted in a decrease in the activity level by a factor of 2.

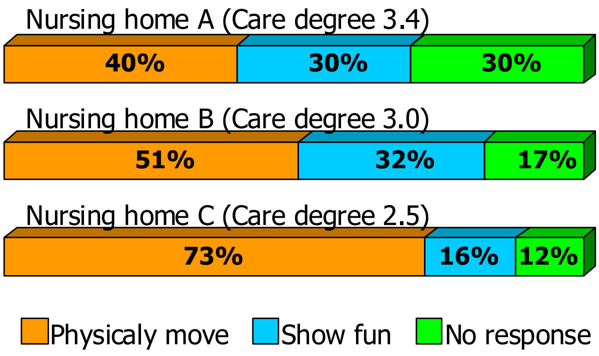


**Fig.9 Evaluated reaction of subjects at 3 different nursing homes**

### *B. Control of Pet Robot by Subject*

Most long-stay residents of nursing homes had been accustomed to keeping dog(s) and walking with the animal(s) when they were younger. Although it is known that walking with animals has a positive effect both physically and mentally, many difficulties prevented the subjects from walking together with their living dog(s). Walking indoors with a robotic dog is, however, still possible if the robot can be easily controlled. If this were possible, it could be expected to bring about a positive attitude toward participating in a rehabilitation program.

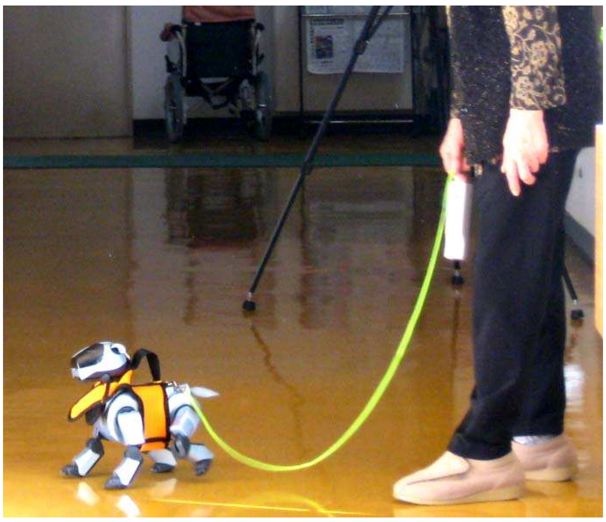

**Fig.10 Walking with the robotic dog AIBO**

In this study, a simple control system was developed using a motion sensor so that a geriatric person with physical and mental difficulties can make AIBO understand his/her instructions. A commercially available game controller, “Wii” (Nintendo), was used for this purpose. In this system, an acceleration signal from the motion sensor is transmitted through a Bluetooth network to the server PC. The server then calls the control program and controls AIBO through conventional wireless LAN. During the rehabilitation activities, AIBO was dressed in a vest and tied with reins in order to imitate a living dog. A preliminary experiment was performed as shown in Fig. 10 for a woman who was able to walk by herself and who kept a small dog before entering the nursing home. The motion sensor was placed in her right hand and it detected her hand movement as she followed the walking steps of AIBO. The activity of walking with AIBO reminded her of memories of her younger days when strolling with a living dog and gave her a feeling of pleasure which made it possible for her to walk around as part of the rehabilitation program inside the nursing home.

## V. CONCLUSION

The application of the robotic dog AIBO to rehabilitation was examined from several viewpoints. As for the present status of AI robots, a remote controlled robot is much more reliable and effective than an autonomous robot for use in rehabilitation. However, one of the key issues that need to be addressed is how to develop a controller that is small, simple and user friendly and which can be ultimately used by the patient. Although accumulation of quantitative data is necessary to arrive at a concrete conclusion, the preliminary results of this study have shown the promising potential of robotic dogs for rehabilitation.

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## REFERENCES

[1] E. Ohkubo, T. Negishi, Y. Oyamada, R. Kimura, and M. Naganuma, “Studies on necessary condition of companion robot in the RAA application”, in Proc. 2003 IEEE Intern. Symp. on Computational Intelligence in Robotics and Automation, pp.102-106, 2003

[2] M. Kanamori, M. Suzuki, H. Oshiro, M. Tanaka, T. Inoguchi, H. Takasugi, Y. Saito, T. Yokoyama, “Pilot study on improvement of quality of life among elderly using a pet-type robot”, ibid. pp. 107-112, 2003

[3] T. Tamura, S. Yonemitsu, A. Itoh, D. Oikawa, A. Kawakami, Y. Higashi, T. Fujimooto, and K. Nakajima, “Is an Entertainment Robot Useful in the Care of Elderly People With Severe Dementia?”, J. Gerontology Series A: Biological Sciences and Medical Vol.59 pp. 83-85, 2004

[4] A. Libin and J. C.-Mansfield, “Therapeutic robocat for nursing home residents with dementia: Preliminary inquiry”, American J. Alzheimer's Disease and Other Dementias, Vol. 19, pp. 111-116, 2004

[5] W. Stiehl, J. Lieberman, C. Breazeal, L. Basel, L. Lalla, and M. Wolf, "Design of a Therapeutic Robotic Companion for Relational, Affective Touch", in Proc. 2005 IEEE Intern. Workshop on Robots and Human Interactive Communication, pp. 408-415, 2005

[6] T. Shibata, "An overview of Human Interactive Robots for Psychological Enrichment", in Proc. the IEEE, Vol.92, pp.1749-1758, 2004

[7] M. M. Baun, N. Bergstrom, N. F. Langston, and L. Thoma, "Physiological Effects of Human / Companion Animal Bonding", Nursing Research Vol.33, pp.126-129, 1984

[8] G. F. Melson, P. H. Kahn, Jr., A. M. Beck, B. Friedman, T. Roberts, and E. Garrett, "Robots as Dogs? – Children's Interactions with the Robotic Dog AIBO and a Live Australian Shepherd", in Proc. the SIGCHI Conf. on Human Factors in Computing Systems, pp. 1649-1652, 2005

[9] L. Odetti, G. Anerdi, M. P. Barbieri, D. Mazzei, E. Rizza, P. Dario, G. Rodriguez, and S. Micera, "Preliminary experiments on the acceptability of animaloid companion robots by older people with early dementia", in Proc. Conf. IEEE Eng. Med. Biol. Soc. pp. 1816-1819, 2007

[10] R. Takahana, M. Miyachi, and M.Okuyama, "Examination of play therapy using AIBO on the girl with Asperger's syndrome"(in Japanese), in Proc. 2004 Annual meeting SI division of SICE, pp.86-87, 2004

[11] An outline of robots are shown in following Web sites
AIBO, http://support.sony-europe.com/aibo/,
NeCoRo, http://www.necoro.com/home.html,
Paro, http://paro.jp/english/,

[12] M. Shioya, E. Ohkubo, T. Sasaki, R. Kimura, and M. Naganuma, "Evaluation of temporal change of patient concentration during Robot Assisted Activity by means of eye contact analysis", Proc. of SICE Annual Conference 2005, pp.2576-2579, 2005

[13] E. Ohkubo, H. Umino, M. Shioya, T. Tetsui, R. Kimura. M. Naganuma. N. Kato, and S. Sato, "Investigation of operator-friendly remote control robot system for RAA/RAT using WWW browsing software", in Proc. 3rd Int. Conf. on Soft Computing and Intelligent Systems, pp. 1490-1494, 2006