https://doi.org/10.20965/jrm.2021.p0730

Paper:

Method to Record and Analyze the Operation of Seal Robot in Elderly Care

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[Received February 22, 2021; accepted June 2, 2021]

Robot therapy, a mental health care through interactions with robots, has attracted attention as a new method of dementia care. In particular, the therapeutic seal robot named "PARO" is being widely used. When using PARO in elderly facilities, caregivers called "handlers" encourage the elderly people to interact with PARO. However, the usage of PARO was left to the handlers itself. Therefore, there was no intended effect in certain cases. To solve this problem, this study aims to develop a method to record the behaviors of handlers and the reactions of elderly people during the robot therapy and a method to support planning by analyzing the recorded data. A Bayesian network was applied to analyze the relationship between the handler's behavior and the elderly people's reactions. To verify usefulness, the experiment was conducted at four elderly facilities between November 2019 and January 2020. The participants were 12 handlers and 21 elderly people. We observed the robot therapy using PARO for 20 min, and subsequently, conducted interviews. Consequently, a model that visualized the relationship between the handler's behaviors and the elderly people's reactions was obtained from 40 observed cases. The interviews confirmed that the model was useful for planning a robot therapy.

Keywords: robot therapy, PARO, elderly care, human-robot interaction, Bayesian network

1. Introduction

Recently, the aging population has become increasingly prominent in several developed countries, including Japan. The number of elderly people requiring care is increasing rapidly. At elderly care sites, high-quality and efficient care services must be provided using fewer caregivers. Accordingly, animal-assisted therapy (AAT) and animal-assisted activities (AAA) are becoming widely used as medical applications in hospitals and nursing homes [1], particularly in the USA. AAT and AAA are expected to have several effects, such as psychological, physiological, and social effects. However, most hospitals and nursing homes, particularly in Japan, do not allow animals because they are afraid of the negative impact of animals on human beings, including allergic reactions, infections, bites, and scratches [2]. To address this problem, a robot therapy, which uses robots as substitutes for animals in AAT and AAA, has attracted attention as a new method for elderly care, targeting people in medical and welfare institutions where animals are not allowed [2]. In particular, a seal-type mental commitment robot named PARO was developed for a robot therapy and used at pediatric hospitals and facilities for elderly people in several countries [2–7]. Several studies have investigated the effectiveness of PARO, such as psychological effects [8–11], physiological effects [10], and social effects [8, 9, 12]. In these studies, caregivers, called "handlers," play a critical role in encouraging elderly people to interact with PARO, with the aim of obtaining expected effects. However, few studies have been conducted to help handlers to effectively use PARO. Therefore, currently, the method of using PARO highly depends on the knowledge and skills of each hander. This hinders several elderly care sites from obtaining the expected outcomes of the robot therapy.

To address this problem, this study aims to develop a systematic method to support handlers to effectively use PARO. The proposed method aims to record the handler's actions and patient's reactions and to develop a protocol for using PARO based on the results of the recording method. The effectiveness of the proposed method was validated by multiple experiments.

Table 1. Representative studies on the robot therapy using PARO.

References	Participants	Setting	Approaches before / during session	Observed effects
Robinson et al. [8]	40 retirement home residents aged 55–100 years in New Zealand.	All residents had a chance to interact with PARO during the sessions.		Decreased loneliness.
Shibata et al. [9]	26 participants aged 73–93 years. Certain participants were diagnosed with dementia.	A desk was prepared to set the robot, and eight or less elderly people were arranged to surround the desk.	Researchers explained the investigation to the participants.	Improved the mood state, brought vigor, and promoted conversations.
Shibata [10]	Elderly people with mild to severe dementia in Denmark and the United States.	Two PAROs were placed at the center of a table around which 5–10 patients were seated. The patients freely interacted with PARO during the session.	Caregivers were asked to maintain the records of PARO's effects and interesting cases. Meetings were arranged to exchange ideas (in the case of Denmark).	Improved depression, behavioral problems, and brain activities in the elderly with dementia. Stimulated their brain areas related to speech and emotions.
Jøranson et al. [11]	60 residents aged between 62 and 95 years with a dementia or cognitive impairment diagnosis.	All participants sat close together in a half-circle without a table in front of them. The activity leader promoted interactions with PARO.	A protocol was developed for the PARO program. Staff members participated in a mandatory PARO training course.	Reduced symptoms of agitation and depression. Increased social interactions within the group setting.
Wada and Shibata [12]	11 women and one man aged 67–89 years.	Two PAROs were placed on tables in public areas. Residents could play with PARO as they wished.	Researchers explained PARO's functions and operations as a robot to residents.	Residents had denser social ties and were encouraged to communicate.
Saito et al. [13]	20 participants, aged 84.3±7.6 years. Certain participants were diagnosed with dementia.	A desk was prepared to set the robot, and eight or less senior people were arranged to surround the desk.		The restoration degree to the stress significantly increased. The whole stress load degree slightly increased.
Bemelmans et al. [14]	71 participants in 6 different locations in the Netherlands.	PARO stayed on a table such that the participant could interact with it. The care provider stimulated interactions between the participant and PARO.	Care providers participated in a two-week training course that introduced PARO, the intervention protocols, and their goals.	Showed effectiveness for interventions aiming at a therapeutic effect.

The remainder of the paper includes the following sections. Section 2 provides the motivation for this study based on a review of existing literature. Section 3 introduces the research methodology adopted in this study. Section 4 provides the proposed method, and Section 5 presents the results of the experiments. Sections 6 and 7 present the discussion and conclusion, respectively.

2. Literature Review and Research Gaps

2.1. Literature Review on the Robot Therapy Using PARO

Table 1 summarizes representative studies that use PARO for elderly care. More comprehensive and detailed reviews were presented by Abdi et al. [3], Bemelmans et al. [4], and Broekens et al. [5]. Similar to AAT and AAA, several studies have investigated psychological effects, such as loneliness [8], vigor [9], and depression [10, 11], physiological effects such as effects on brain activities [10], and social effects such as socialities [12] and communication [9, 11]. For example, Robinson et al. investigated the psychosocial effects of PARO in a rest home / hospital setting in comparison with a control group [8]. They revealed that residents who interacted with the robot had significant decreases in loneliness compared to that in the control group. Wada and Shibata adopted a free pile sort method [15] to evaluate the psychological and social influences of the robot regarding social interactions between residents and PARO [12]. They noted that PARO enabled the residents to cultivate denser social ties and encouraged them to communicate with others. Shibata measured brain activities using electroencephalogram (EEG) and functional near-infrared spectroscopy (fNIRS) [10]. The EEG results showed that PARO improved the brain activities of the elderly; the fNIRS results showed that interactions with PARO stimulated the brain areas related to speech and emotions in the elderly.

To effectively use PARO, these studies adopted various approaches before and/or during the sessions where participants, that is, the elderly, interacted with PARO. Before the sessions, for example, Wada and Shibata explained PARO's functions and operations as a robot to residents [12]. Shibata arranged meetings among PARO users to collect data and cases, enabling participants to exchange ideas [10]. Bemelmans et al. organized a two-week training course for care providers to introduce PARO, the intervention protocols, and their goals [14]. The protocols described the course of the intervention in simple steps, used in the context of the specified goals defined for the particular participant. Furthermore, Jøranson et al. developed a protocol for the PARO program [11] in which each session started with a presentation of PARO as an articulated toy to reduce misinterpretations. Moreover, during the sessions, several studies allowed patients to freely interact with PARO [8, 12], whereas certain studies defined a more detailed setting. For example, Shibata et al. [9] and Saito et al. [13] prepared a desk to set up PARO, and up to eight or less elderly people were arranged to surround the desk. Furthermore, Bemelmans et al. [14] and Jøranson et al. [11] stimulated interactions between the participants and PARO if necessary. Jøranson et al. designated an activity leader to sit in front of the group, promote interactions with PARO, and distribute it to participants' laps for equal periods of time [11].

2.2. Research Gaps for an Effective Use of PARO

As described above, existing studies adopted various approaches before and/or during the sessions such that the elderly could effectively interact with PARO. In these approaches, handlers play a critical role, and therefore certain studies have provided training courses [14] and protocols [11, 14] for handlers. However, this knowledge and information are currently fragmented. Limited studies have discussed a systematic method that supports handlers to determine how to use PARO depending on the expected effects.

3. Research Methodology

This study aims to develop a systematic method that supports handlers to effectively use PARO. The proposed method includes two methods. One method aims to record the handler's actions and patient's reactions, whereas the other method aims to develop a protocol for using PARO based on the result of the recording. To achieve these objectives, hypothetical methods were first developed based on existing studies and then improved using a pilot test in a rehabilitation hospital. Subsequently, the effectiveness of the methods was validated by experiments in multiple cases. This study was conducted with the approval of the research ethics committee of Hino Campus, Tokyo Metropolitan University.

4. Method to Support Handlers to Use PARO

4.1. Check Sheet to Record Handler's Actions and Patient's Reactions

This study developed a check sheet based on the concept of rubrics to record the handler's actions [16] (**Table 2**). Rubrics are widely used in assessing the performance of students, objectively and credibly [16]. The benefits of using rubrics include an increased consistency of scoring, the possibility of facilitating a valid judgment of complex competencies, and promoting learning [16]. Similar to rubrics, the proposed recording method included evaluation criteria and quality definitions. The evaluation criteria corresponded to factors that had to be considered when determining the quality of a handler's actions. Therefore, this study selected these factors based on the existing guidebook on the robot therapy [17]. The guidebook provides good practices on handlers' behaviors and communication, enabling the stimulation of interactions between patients and PARO. Based on the practices, this study particularly focused on 13 factors that could be observed in several cases (check the first column in **Table 2**). These factors focused on actions during interactions between patients and PARO, as well as those before and after them. For each factor, a quality definition was provided as a detailed explanation of what a handler had to do to achieve a certain quality. For example, with regard to the factor "place PARO where everyone can see," its quality definition included four levels: "place PARO where nobody can see, such as outside the group (not met)," "place PARO where someone finds it difficult to see (unsatisfactory criteria)," "place PARO where everyone can see (minimal criteria)," and "place PARO where everyone can see easily, such as the center of the group (expected criteria)."

With regard to the check sheet for recording the patient's reactions, 15 items were identified based on existing studies [18] (**Table 3**). These items included patients' attitudes toward PARO, such as "spontaneous interaction," "encouraged interaction by others," and "indifference," as well as states during interactions, such as "smile," "stroke PARO," and "stare at PARO."

Table 2. Check sheet to record handler's actions.

	Not met	Unsatisfactory criteria	Minimal criteria	Expected criteria
Presenting PARO				
1. Place PARO where everyone can see.	Place PARO where nobody can see, such as outside the group.	Place PARO where someone finds it difficult to see.	Place PARO where everyone can see.	Place PARO where everyone can see easily, such as the center of the group.
2. Place PARO where everyone can reach.	Place PARO where nobody can reach, such as outside the group.	Place PARO where someone finds it difficult to reach.	Place PARO where everyone can reach.	Place PARO where everyone can reach easily, such as the center of the group.
3. Talk to encourage interactions with PARO.	No talk.	Talk, but do not encourage interactions with PARO.	Talk to encourage interactions with PARO.	Talk to encourage interactions with PARO, and then the patient begins interactions smoothly.
During interactions with PARO				
4. Match eye level with the patient.				
5. Look at the patient.				
6. Speak politely.				
7. Speak with a clear voice.				
8. Behave naturally.				
9. Listen to the patient.				
10. Consider the patient who is reluctant to interact.	Force an interaction or ignore the patient.	Disturb the patient's pace and encourage an interaction.	Encourage interactions at the patient's pace.	Let the patient participate in the interaction at his/her pace.
11. Use PARO as a group activity.	No/interrupt interactions with PARO.	Only certain patients interact with PARO.	Can consider the patients who are not interacting with PARO.	Can use PARO to meet the patients' pace in the group.
12. Have natural conversations.	No conversation.	Less conversation.	Several conversations.	Natural conversations.
Withdrawing PARO				
13. Ask the patient to return PARO.	Take away PARO forcibly.	Receive PARO but disturb the patient's pace.	Ask the patient to return PARO, and then receive it.	Ask the patient to return PARO at his/her pace, and then receive it.

4.2. Method to Develop a Protocol to Use PARO

This study adopted a Bayesian network [19] to support handlers to effectively use PARO based on the recording method's results. A Bayesian network is a graphical model to represent conditional dependencies between a set of variables. The dependencies are quantified by conditional probabilities for each variable given its parents in the network. The network supports the computation of the probabilities of any subset of variables, given evidence about any other subset [20]. Recently, Bayesian networks have been applied in various fields, including elderly care, such as monitoring elderly [21] and diagnosing dementia [22].

The proposed method developed a Bayesian network based on the relationship among handler's actions, patient's reactions, and the behavioral and psychological symptoms of dementia (BPSD). The variables of the handler's actions corresponded to the factors in the handler's check sheet, whereas those of the patient's reactions corresponded to the items in the patient's check sheet. Furthermore, BPSD variables were extracted from existing studies [23], such as "physical violence and abusive language," "anxiety and frustration," and "wandering." The variables of BPSD were set as the parent node of the others because the patient's reactions to the handler's actions changed depending on the patient's BPSD. The conditional probability among these variables was obtained from the results of the recording method; thus, a Bayesian network was developed such that handlers could estimate the posteriori probability of performing a handler's action when a certain patient's reactions were observed. It was assumed that the estimated posteriori probability would enable handlers to determine which actions should be performed to elicit the patient's expected reactions. Furthermore, this posteriori probability would change depending on the observed patient's BPSD.

Table 3. Check sheet for recording patient's reactions.

Attitude towards PARO:

- Spontaneous interaction
- Encouraged interaction by others
- Indifference
- Rejection
- No interaction

Behaviors during the activity:

- Smile
- Stroke PARO
- Stare at PARO
- Keep PARO away
- Hit PARO
- Talk to PARO
- Hug PARO
- Conversation with participants
- Conversation with caregivers
- Consideration for other participants

5. Experiment

5.1. Experimental Method

To validate the effectiveness of the proposed method, experiments were conducted at four facilities in Tokyo, Japan: a group home, a special elderly nursing home, and two day care centers. With regard to handlers, the participants of the experiment were 12 staff members (11 women and one man) aged 44.3±13.5 years: nine caregivers, two occupational therapists, and one life consultant. Further, the patients participating in the study included 20 women and one man over 65 years old who had mild to moderate dementia symptoms. The patients could recognize PARO as an animal or robot and interact with PARO in a calm manner. Before the robot therapy session, we explained PARO's functions and operations to the handlers. Subsequently, similar to existing studies [9, 13], the session was conducted for 20 min for approximately four patients, thus preventing them from being bored to interact with PARO. A desk was prepared to set PARO, and patients were arranged to surround the desk. During the session, the patients could freely interact with PARO. In this experiment, the handler's actions and patient's reactions were recorded by the authors and facility staff using the proposed check sheets. After the session, further interviews were conducted with the facility staff to assess the BPSD of each patient.

5.2. Experimental Result

Based on the results, a Bayesian network was developed using BayoLink, a software for Bayesian network construction [a]. **Fig. 1** illustrates a part of the developed network. For example, BPSD "anxiety and impatience" was associated with the handler's actions – "match eye level with the patient" – and the patient's reactions – "talk to PARO." **Fig. 2(a)** depicts a part of the estimated posteriori probability of handler's actions when a certain patient's reaction – "hug PARO" – was observed. For example, the posteriori probability of "place PARO where everyone can see" was "unsatisfactory criteria: place PARO where someone finds it difficult to see (8%)," "minimal criteria: place PARO where everyone can see (44%)," and "expected criteria: place PARO where everyone can see easily (48%)." The posteriori probability of "place PARO where everyone can reach" was "unsatisfactory criteria: place PARO where someone finds it difficult to reach (47%)," "minimal criteria: place PARO where everyone can reach (17%)" and "expected criteria: place PARO where everyone can reach easily (36%)." This result suggested that a handlers' action – "place PARO where everyone can see" – would be relatively important compared to "place PARO where everyone can reach" to elicit patient's reaction "hug PARO." Furthermore, **Fig. 2(b)** presents the result in the case of a patient with BPSD "physical violence and abusive language." In this case, the posteriori probability of certain handler's actions was changed, such as "expected criteria: place PARO where everyone can see easily (from 48% to 56%)" and "expected criteria: place PARO where everyone can reach easily (from 36% to 41%)." This result suggested that these actions were relatively important for encouraging patients with "physical violence and abusive language" to "hug PARO."

6. Discussion

Based on interviews with handlers, we observed the following regarding the effectiveness of the proposed method. First, the proposed Bayesian network structure enabled the estimation of the posteriori probability of performing a handler's action when a certain patient's reactions were observed. The estimated probability could be useful for handlers to determine which actions had to be performed to elicit the expected patient's reactions. For example, the experimental results demonstrated that handler's actions, such as "match eye level with the patient" and "have natural conversations," would be more important to elicit the patient's reaction "talk to PARO." Furthermore, this posteriori probability was changed depending on observed patient's BPSD, such as patients with BPSD "physical violence and abusive language" in **Fig. 2(b)**. This enabled handlers to develop a protocol that provides important handlers' actions to elicit a particular patient's reactions according to their BPSD.

Notably, the proposed method was also effective for training handlers because the check sheet of handler's actions was developed based on the concept of rubrics. The check sheet provided detailed explanations of what a handler had to do to achieve a certain quality of each action, that is, quality definition, and thus was used as a guide to improve the action.

Furthermore, the experiment revealed limitations in the effectiveness and efficiency of the proposed method. First, in the experiment, the handler's actions and patient's reactions were recorded by the authors and facility staff. However, in practical situations, it is difficult to assign

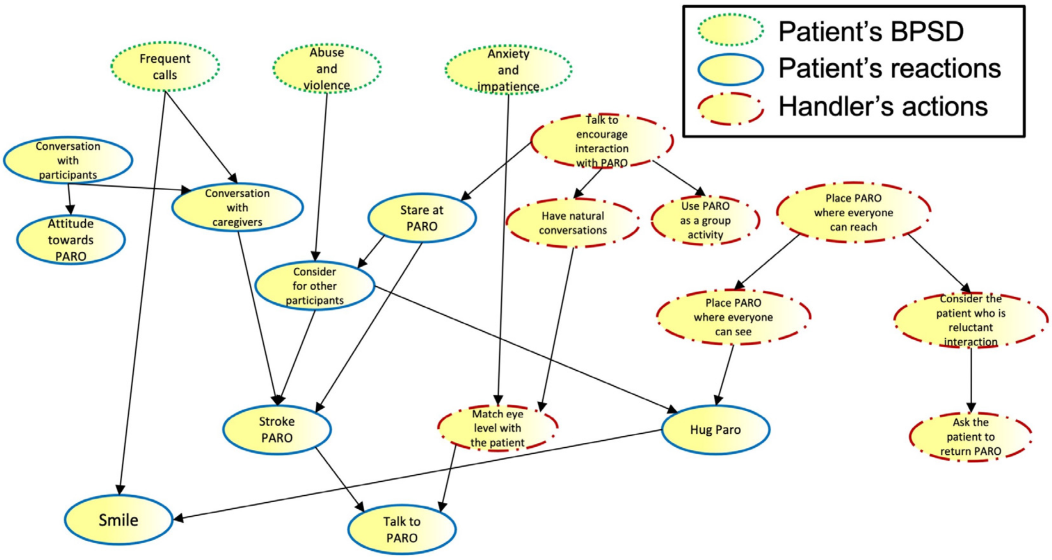
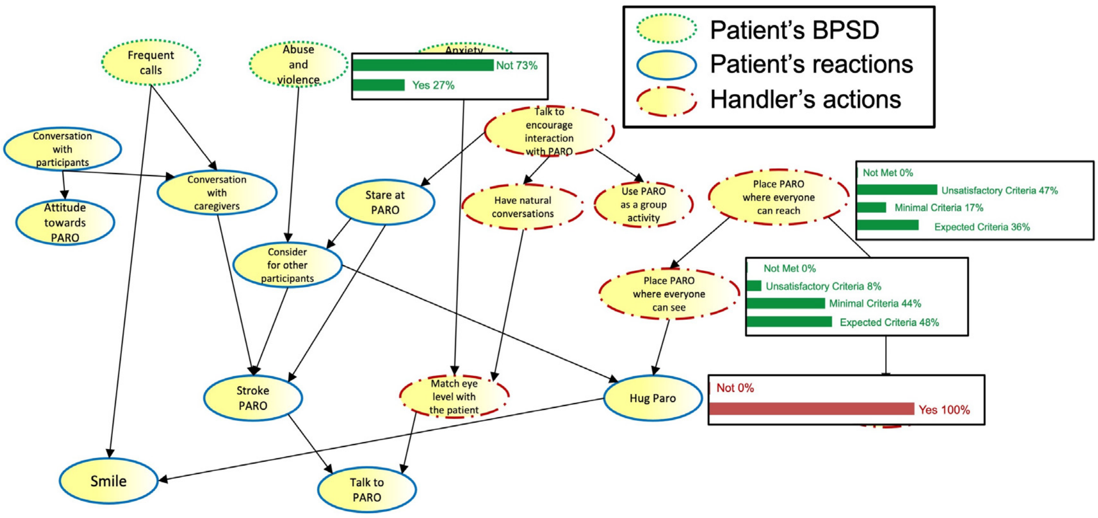
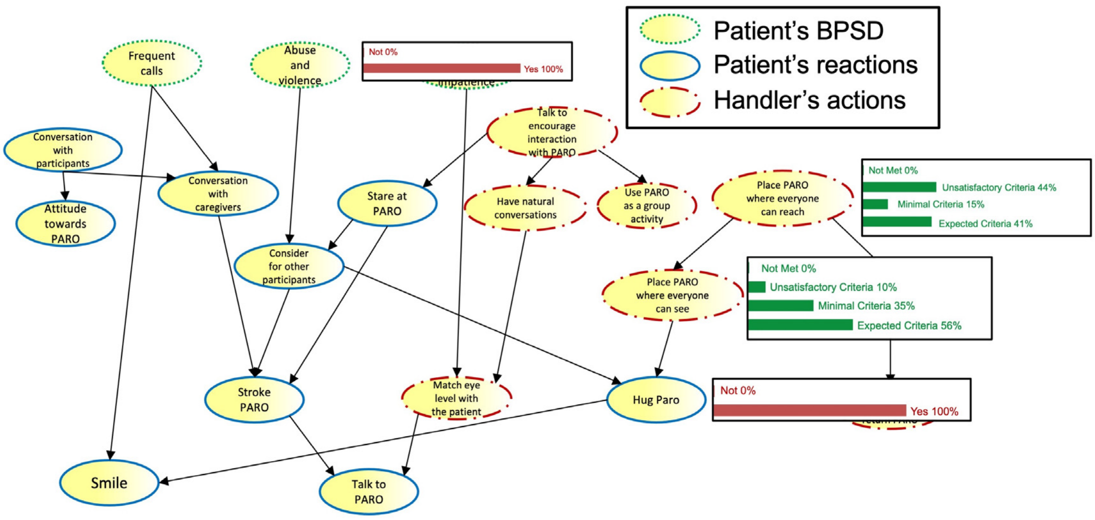


Fig. 1. Conditional dependencies among handler's actions, patient's reactions, and BPSD.



(a) Estimated posteriori probability for all patients



(b) Estimated posteriori probability for patients with "physical violence and abusive language"

Fig. 2. Estimated posteriori probability of handler's actions to patient's reaction "hug PARO."

a person, in addition to handlers, to record. This problem could be addressed by the automation of recording using a motion capture technology. Second, it is difficult for handlers to use a Bayesian network and understand its result. Additional supports, such as guidelines and education programs, must be developed. Furthermore, the validity of the estimated posteriori probability validity must be improved by collecting data through further experiments.

7. Conclusion

This study developed a systematic method to support handlers to effectively use PARO. In particular, a check sheet based on the concept of rubrics was developed to record the handler's actions. Furthermore, a Bayesian network structure was proposed for developing a protocol for using PARO based on the results of the recording method. Through the experiments, we noted that the proposed methods could help identify important handler's actions for eliciting a particular patient's reactions according to their BPSD. The method was also effective in training handlers.

Future works include the automation of recording using a motion capture technology, development of additional supports, and data collection through further experiments.

Acknowledgements

This work was supported by JSPS KAKENHI, Grant Number 17K00440. The authors would like to thank the staff of the facilities for providing this research with invaluable data for the experiment.

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