Preliminary study on the benefits of using the robot PALRO® in facilitating leisure programs for older adults with dementia

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Abstract

Background: The use of humanoid-shaped robots may have a positive influence on older adults with dementia and their caregivers. However, there is a dearth of studies with a higher level of evidence. Thus, this quasi-experimental study serves as a preliminary investigation of using PALRO, a humanoid-shaped robot, in facilities' leisure programs for older adults with dementia.
Objective: To elucidate the effects of a leisure program that uses the language-capable humanoid robot PALRO on older adults with dementia.
Method: A one-group pretest-posttest design was done while employing Person-Centered Care principles and the associated outcome measure, Dementia Care Mapping (DCM). Older adults with dementia from long-term care facilities and group homes participated in a PALRO-facilitated leisure program. Data was collected using methodological observation to record the behaviors and well-being. Non-parametric inferential statistics were used to determine significant changes between pre-and post-intervention.
Results: Among the 77 participants, 84.4% had a significant improvement in their well-being after the program. This improvement indicated a 'positive state' as defined in DCM. The participants elicited behaviors within the following categories during the program: interaction with an object, expressive activities, leisure activities, intellectual activities, articulation, and physical exercises.
Conclusion: Significant percentage of older adults with dementia staying in long-term care facilities and group homes exhibited a 'positive state' towards a PALRO. The robot-mediated leisure program may be able to provide an opportunity to elicit positive reactions from older adults with dementia regardless of their level of cognitive functioning or independence.

Keywords: geriatrics, humanoid robot, leisure program, long-term care facility

INTRODUCTION

In May 2014, a 'new industrial revolution by robots' was declared by the Japanese Ministerial Council Meeting of the Organization for Economic Co-operation and Development thereby ushering Japan's 'Robot Strategy' (Japan Economic Revitalization Headquarters, 2015). In effect, the market of robotic care devices has been growing and the development, promotion, and use of more than 100 medical-related devices were financially supported. To date, various projects have been promoted in line with the robot-related policies of each ministry.

Japan's society has the highest aging rate worldwide, with older adults comprising 28.7% of the population as of the year 2020 (D'Ambrogio, 2020). Moreover, by 2025, the Japanese government expects that approximately 20% of the total population will develop dementia with the prevalence of dementia for persons aged 65 and older increasing from 15% (4.62 million) in 2012 to 25% by 2025 (Cabinet Office, 2016; Ministry of Health, Labor and Welfare, 2017). This demographic significance makes dementia care an urgent issue. Human interaction and support are essential in caring for older adults with dementia. However, labor shortages and caregiver fatigue can impede optimal care of older adults

Figure 1. PALRO

with dementia. With the progression of dementia, the amount of assistance required for older adults with dementia increases. Thus, it is beneficial to consider the application of robotic devices and the environment as a support tool in assisting caregivers to facilitate the engagement and participation of older adults with dementia. Recently, it is becoming more common to utilize artificial intelligence and robots to support one's daily life.

According to Shishehgar and colleagues (2018), using robotic technologies to help elderly people's problems can have positive effects on their lives. Most robots used in healthcare are modeled after animals. For instance, the dog-robot 'AIBO' was found to be effective in reducing the loneliness of residents in a long-term care facility (Banks et al., 2008). Another, a harp seal robot named 'PARO' was developed by Japan's Agency of Industrial Science and Technology (AIST), as a Biofeedback Medical Device for Mental Health. As of 2021, approximately 7,000 PAROs were in use in more than 30 countries (Shibata, 2021). When PARO is used as a support medium, it can reduce depression, anxiety, and loneliness in older adults with dementia, as well as increase their enjoyment and provide respite from their caregivers (Inoue et al., 2021; Moyle et al., 2013; Moyle et al., 2017, 2018; Robinson et al., 2013).

While animal-modeled robots such as PARO have clear benefits to mental health, humanoid-shaped robots were found to possess different benefits as people's impressions tend to differ between humanoid-shaped and animal-modeled robots (Hashimoto et al., 2018). The use

of humanoid-shaped robots in caring for older adults with or without diminished cognitive function resulted in brighter facial expressions and increased interactions (Ikeda et al., 2018; Noguchi et al., 2019; Obayashi, Masuyama, et al., 2018). Additionally, certain humanoid-shaped robots can be utilized in robot-assisted activity (RAA) for older adults, positively influencing motor functions (Taniguchi et al., 2019). Contrary to using robots as a support medium, RAA is a structured activity wherein a robot is used as an activity facilitator. In a study using a humanoid-shaped robot to facilitate activities of 10 residents in an elderly care facility, it was postulated that RAA can be used for emotional and recreational therapies within medical facilities for older adults (Kanoh et al., 2011).

A humanoid-shaped robot used in daycare facilities for older adults is PALRO (*Figure 1*, Fujisoft Incorporated). It is small, portable, and has a wide variety of features and functions such as singing and dancing. PALRO also has an advanced voice recognition function suitable for individuals who require language-related intervention and services (Fujisoft Incorporated, n.d.). However, PALRO is unable to recognize verbal commands whenever it is talking. Some of PALRO's other features that can be used for recreational purposes are the provision of stories, exercises, games, and quizzes, connecting to the internet to send and receive mail, and taking photos. PALRO was utilized in this study as it offered Japanese language-based features appropriate to be used for older adults, does not require a complex setup before usage, and was readily purchasable.

A conference proceeding by Hamada and colleagues (2016) reported the use of PALRO to facilitate physical activity for older adults in the Japanese context, and the findings suggested better engagement and satisfaction of the participants. In terms of peer-reviewed research, two studies explored the benefits of communication robots including PALRO in a residential setting (Obayashi, Kodate, et al., 2018; Obayashi et al., 2020). The robot was placed on each participant's bedside table and was primarily used as a combination of predominantly individual and group intervention. This arrangement requires many numbers of robots. However, considering the cost of one business model PALRO being JPY 670,000 (or approximately USD 5,700) (Fujisoft Incorporated, n.d.), such a setup may not be viable for practical application. Thus, there is a need to know the benefit of PALRO when used within group sessions alone. This study serves as a pilot investigation for future studies involving PALRO as a group facilitator with larger sample size.

Among the activities that use humanoid robots, leisure activities were selected as most Japanese long-term care facilities provide leisure activities for the residents to improve their quality of life. These activities increase their daytime activity, allow them to spend meaningful time, and encourage social participation. Hence, this paper aimed to elucidate the effects of a leisure program that uses the language-capable humanoid robot PALRO on older adults with dementia.

METHODOLOGY
Theoretical grounding
The principles of person-centered care (PCC) guided this research (Kitwood, 1997). The core assumption of PCC is that the personhood (sense of self) of a person with dementia can be maintained by meeting five fundamental psychosocial needs namely: comfort, identity, attachment, occupation, and inclusion (Kitwood, 1997). In PCC, signs of 'positive state' among older adults with dementia include showing self-confidence, self-assertion, a relaxed body, sensitivity to others' needs, initiative to interact with others, using and responding to humor, creatively expressing oneself, trying to be helpful, showing affection, and expressing various emotions. As such, this principle informed the thinking of the researchers in the creation of the intervention program and identifying outcomes sought in this study.

Research design
This study utilized a one-group pretest-posttest design. This design is often used to serve as a pilot effort before conducting a large experiment. In this study, the participants' behaviors were observed before, during, and after the leisure program.

Recruitment and participants
A request letter for the research project participation was mailed to long-term care facilities and group homes within Kanagawa prefecture, Japan. These facilities were randomly selected from the official homepage of the Kanagawa government (Kanagawa Prefectural Government, 2021). Once a facility expressed an interest to participate, the principal investigator (PI) scheduled a visit to explain the details of the research project. When the facility consented, a recruitment poster was displayed inside the facility. The details of the project were explained to interested residents and their family (or legal guardian, if appropriate) verbally and in writing. A signed letter of consent was then obtained. The letter of consent and poster clearly stated that the research had nothing to do with the facility's services and that cooperation was voluntary. The date and time of implementation were agreed upon by the facility and the PI.

G*Power is a tool used to compute effect sizes and other statistical power analyses (Buchner et al., 2021). Utilizing G*Power, a sample size of 75 was calculated with the effect size at 0.5, test power at 0.95, and significance level at 0.01. However, to provide ample leeway for the unusable data that may be caused by attrition, we collected a total of 100 participants. Inclusion criteria were residents with dementia who were able to participate in a leisure program spanning 30 minutes. Residents with severe consciousness disorders, visual impairment, or hearing impairment were excluded from this study as these individuals exhibit comorbid conditions which may negatively affect full engagement with the program -- specifically with engaging with PALRO's movement and/or speech.

Data collection
On the day of the program, the facility staff confirmed the physical condition and status of the subjects before participation. Information on age, gender, diagnosis, nursing care level, degree of independence of older adults with dementia was obtained from the facility's most recent record. The degree of independence in daily living is a seven-level indicator used in the certification of the nursing care level. Level I indicate the highest independence, followed by II (a and b), III (a and b), IV, and M. The nursing care level is a five-level classification system (1 as the least assistance required and 5 as the most) devised to categorize an individual's required care and access to support under the Japanese Long-term Care Insurance System.

To begin, the facility staff ushered up to 10 participants to the communal space and positioned them in a semicircle around PALRO. Next, the facilitator (an occupational therapist who was not a part of the research team) introduced PALRO. Thereafter, a 30-minute leisure program was led by PALRO, wherein PALRO seamlessly transitioned through different program components, including self-introduction (2 minutes), ice breaker / small talk (3 minutes), light exercise (5 minutes), quiz, and game (5 minutes), seated exercise while PALRO plays music (5 minutes), short stories (2 minutes), take a photo (5 minutes), and closing remark (2 minutes). During the program, the facility staffs were free to join the participants. The facilitator interjected and assisted participants as needed (such as when PALRO fails to understand the participant due to speaking on a low volume or strong accent), as well as encouraged the participants to actively interact with PALRO throughout the humorous conversations. At the end of the program, the facilitator closed the session.

Outcomes
Dementia Care Mapping (DCM) is a method used to methodologically record the behaviors

Table 1. Participants' characteristics

Variable	N=77	Percentage
Gender		
Male	9	11.7%
Female	68	88.3%
Age (Mean ± SD)	86.74±6.19	100%
Diagnosis		
Alzheimer's dementia	53	68.8%
Vascular Dementia	9	11.7%
Other Dementia	15	19.5%
Nursing care level		
Care level I	7	9.09%
Care Level II	17	22.1%
Care Level III	25	32.5%
Care Level IV	23	29.9%
Care Level V	5	6.49%
Degree of independence		
I	3	3.90%
II (a & b)	24	31.2%
III (a & b)	36	46.8%
IV (a & b)	14	18.2%
M	0	0.00%

of persons with dementia to assess their quality of life within care facilities (Brooker & Surr, 2005; Fossey et al., 2002). It was based on the concept of PCC. The DCM has a good internal consistency and test-retest reliability (r = 0.55, p < 0.0001) (Fossey et al., 2002). In rating, multiple observers (mappers) record (1) behavior that indicates the most significant care potential and (2) state of the person with dementia every 5 minutes in adherence to the rules stipulated in the DCM manual (Bradford Dementia Group, 2005). (1) The behavior was categorized from the 23-predefined Behavior Category Code (BCC). Description of the codes can be found in the DCM manual (Bradford Dementia Group, 2005). (2) The state was examined based on the Mode and Engagement (ME) coding and recorded according to the Well-Ill-Being (WIB) score. The WIB score is a six-point scale divided into -5, -3, -1, +1, +3, and +5. Of note, +1 indicates a neutral state wherein the subject is aware and focused on the surroundings but is not showing signs of positive or negative mood. Higher scores indicate a 'positive state', while the lower scores indicate a 'negative state'. The individual WIB score was obtained by dividing the ME score recorded before (30 minutes), during (30 minutes), and after (30 minutes) the leisure program. The group WIB before, during, and after the program was derived by getting the mean score during the respective periods.

In this study, two certified care workers with advanced dementia care mapping qualifications (called mappers) concurrently and unobtrusively observed the participants. They worked as care aids in different long-term care facilities wherein they had to perform mapping daily. Thus, they possess the skills to handle data collection for research purposes. The mappers had a relatively high inter-rater match of 87%. The observation acquired was verified by discussing with the facility staff and comparing official records.

Data analysis
The result was analyzed using the prescribed DCM analysis method. Descriptive statistic was used to provide a rich picture of participants. Exploratory statistical analysis, specifically Spearman's rank correlation, was used to confirm correlation among the subjects' age, nursing care level, daily living independence degree, and individual WIB score during the leisure program. The WIB scores were compared using the Wilcoxon rank-sum test, using gender as a group element. The Friedman test was performed on the group WIB score before, during, and after the leisure program; thereafter, a post-hoc test by Bonferroni was performed (software used: R Commander 3.4.1). The main outcome was the difference in WIB score compared between before, during, and after the leisure program. The first minor outcome was the difference in group WIB score during the leisure program correlating with the age, care level, and degree of independence. The second minor outcome was the difference in WIB scores between the male and female subjects.

Research ethics
The research was conducted while upholding ethical standards under the Declaration of Helsinki. This research was approved by the Tokyo Metropolitan University Research Safety and Ethics Committee in 2014 (approval number: H-158). Consents from the cooperating facility's managers, participants, and legal guardians were obtained. Additionally, this study is registered with the University hospital Medical Information Network – Clinical Trials Registry (UMIN000039473).

RESULTS
Data of 77 participants from five facilities (four long-term care facilities, one group home) were obtained and analyzed. Each program session was attended by a maximum of ten participants, for a total of ten sessions. The subjects' ages ranged from 67 to 97 years (m=86.7, SD=6.20). The majority were women (88.3%). Information regarding the subjects is shown in *Table 1*.

Behavior categories observed
Six notable behavior categories were observed during the leisure program. Under the category 'Occupation', specific behaviors observed include: *"enjoying while participating in the program conducted by PALRO"* and *"looking at PALRO with deep interest (in that sense of en-*
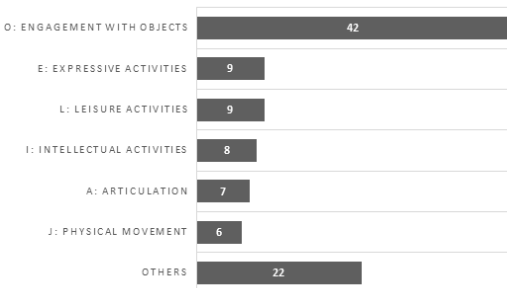
Figure 2. Categories of notable behaviors during the program

gagement with objects)". Out of the 77 participants, two appeared to be disengaged or withdrawn. These two exhibited low wakefulness even before the leisure program. Disengagement was recorded several times before and after the leisure program. *Figure 2* shows the common categories noted during the program.

ME Code observed and WIB scores
The individual WIB scores indicated '<1' for two subjects (2.6%), '1' for ten subjects (13.0%), and '>1' for 65 subjects (84.4%). *Figure 3* reveals the distribution of WIB scores in relation to their nursing care level. The group WIB score during the leisure program was higher than that of before and after, generally indicating a 'positive state'. As normality was not confirmed when the distribution was tested by histogram or quantile-quantile plot, Friedman test was performed to the group WIB scores across time and a significant result was noted ($x2=32.022$, df=2, p=0.0000001113). Therefore, correction via the Bonferroni test was performed for each group. *Table 2* shows the properties and analysis of the group WIB. There were no significant differences in the WIB scores to gender (Wilcoxon rank-sum test, Z – 1.675, p = 0.08539).

Correlation between participant characteristics and WIB scores
No correlation was found between the mean WIB score and age (ρ= -0.181, p = 0.0868) and nursing care level (ρ = -0.192, p = 0.0676). There
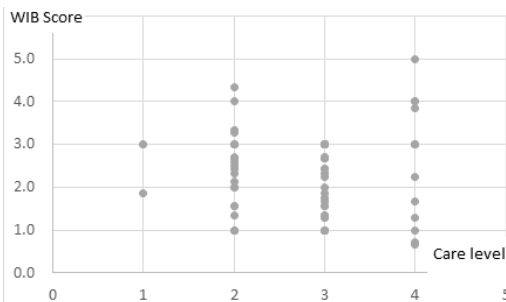

Figure 3. Individual WIB scores during the program per nursing care level

was a weak negative correlation between the mean WIB score and daily living independence degree (ρ = -0.329, p = 0.022).

DISCUSSION
Behaviors observed towards PALRO's leisure program
A PALRO-based leisure program elicits a good response from older adults. Particularly, as engagement with the object (e.g., staring at PALRO) was often recorded, the appearance, voice, and movement of PALRO may attract the attention of older adults with dementia. Multiple activities that can maximize the level of emotions, mood, and engagement were noted.

A systematic review of non-drug therapies for older adults with dementia reported that significant improvements in behavioral and psychological symptoms of dementia were noted in cognitive stimulation therapy (tabletop task using paper and pen), advanced caregiver training (learning about factors that trigger symptoms and its management), out-patient psychotherapy (music therapy, movement therapy, psychodynamic therapy, and sociotherapy), and collaborative care (weekly meetings with a support team, use of web-based meeting scheduling system with patients, and group sessions for oneself and one's family). Conversely, this improvement was not noted in a multisensory environmental intervention (a combination of lighting, music, and aroma stimulation) (Doi-Kanno et al., 2016). Significant effectiveness cannot be achieved through an approach that is dependent on environmental factors alone. PALRO's leisure program is an activity that combines individuals and objects to form robot-mediated leisure conducted by an occupational therapist in cooperation with facility staff. Combining care received from caregivers and robots may potentially elicit a positive response from older adults with dementia.

Change in WIB scores during PALRO's leisure program
The WIB score during the leisure program was higher than that before and after. The mean WIB score (84.40%) during the program was higher than +1. Considering that this is a positive result, we believe that PALRO will be well-received by many older adults with dementia. Conversely, 13.00% of the subjects scored +1. Based on the observation of the occupational therapist and mapper, the remaining 2.60% (two subjects) found it difficult to look at and recognize PALRO. Because of this, both subjects were unable to enjoy PALRO's activity. One subject was categorized under daily living independence level II and nursing care level 2 and the other subject under levels 4 and 5. Additionally, there was no correlation between nursing care level and

Table 2. Properties of group WIB scores before, during, and after the program

	Before	During	After	p-value (Friedman test)
Group WIB score	+1.6	+2.1	+1.4	<0.0001
Standard deviation	0.9	0.9	0.8	
Minimum	-1.0	+0.6	-1.0	
Maximum	+4.5	+5.0	+3.4	
1st quartile	+1.0	+1.3	+1.0	
2nd quartile	+1.4	+2.0	+1.0	
3rd quartile	+2.2	+2.7	+2.0	
Interquartile range	+1.2	+1.4	+1.0	
Interquartile deviation	+0.6	+0.7	+0.5	

pairwise difference test (Bonferroni's multiple test):
 Before vs. During: p = 0.0003 (power = 0.988)
 Before vs. After: p = 0.0825 (power=0.673)
 During vs. After: p < 0.0001 (power=1.000)

the WIB score. Therefore, we believe that gender, age, and nursing care level are unlikely to be confounding factors for the WIB score. The nursing care level is reported to be negatively correlated with the Mini-Mental State Examination results and positively correlated with the Clinical Dementia Rating (Togami et al., 2009). Meanwhile, it is reported to have a strong negative correlation with the Functional Independence Measure (Handa & Imai, 2016). Therefore, the test results for cognitive function may not be correlated with the reaction to the robot. Simply stated, robot-mediated activities may be enjoyed by many individuals regardless of the level of cognitive functioning. A weak negative correlation was found between the WIB score and the level of independence, further research is required to investigate the possibilities for those with a higher level of independence may be able to focus and enjoy the leisure activities with PALRO more. It would be important to examine the contents and methods for providing robot-mediated leisure that is more tailored to specific subjects and facilities through a research design with a high evidence level. This can contribute to building evidence-based services to improve facility-based care provision.

In summary, eighty-four percent of the 77 older adults with dementia staying in long-term care facilities and group homes exhibited a 'positive state' towards a PALRO-facilitated leisure program. Conversely, only 2.60% exhibited a 'slightly negative state'. A significant improvement was noted when comparing the scores that indicate the status of the subjects (WIB score) before and after the program. This improvement indicated a 'positive state' as defined in DCM. The behaviors of older adults with dementia that were more likely to be elicited by the leisure program that used PALRO included engagement with objects, expressive activities, leisure activities, intellectual activities, articulation, and physical exercise. Although the observed reactions were different in each subject, PALRO's leisure program may be able to provide an opportunity to elicit positive reactions from older adults with dementia regardless of their level of cognitive functioning or independence.

Research limitations
The number of male subjects was smaller than that of the female subjects, and the subjects' daily living independence degree and nursing care level required were uneven. As an initial verification of the effectiveness of robot-mediated leisure activity, the purpose of this study was to examine the relationship between the response of older adults with dementia to the leisure program and the daily living independence degree and required nursing care level; however, for further verification of the therapeutic effect, its relationship with other outcomes should also be examined. It should also be noted that this research was a trial, hence the control group was not set.

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