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Tele-Operated Android Robot Reminiscence Group Therapy and Human Coordinated RGT for Older Adults with Dementia: A Comparative Study

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SUMMARY

Background/Purpose: Since being designated a super-aged society in 2007, Japan has faced a shortage of care givers working at nursing facilities. To address this problem, the government has been promoting research into robotics technology. However, social robots in current use have limited communicative ability. We examined the effectiveness of a tele-operated android robot in reminiscence group therapy (RGT) for persons with dementia (PWD), compared to RGT with a human coordinator.
Method: Six PWD from a public facility for senior residents underwent RGT using a tele-operated android robot, *Telenoid R3.* Participants were divided into two groups: RGT with a human coordinator (condition 1), and RGT with the same coordinator, using *Telenoid R3* (condition 2). After the first three sessions, the robot and the human coordinator were substituted in each group, and three more sessions were conducted. Linguistic data comprising the number of utterances, sentence-final particles, and N-gram was collected and analyzed.
Results: Among participants, half (n = 3) showed a significantly higher average number of utterances and sentence-final particles in RGT with condition 1 ($p < .01$, $p < .05$, $p < .01$), while one female participant showed a significantly higher number of sentence-final particles in RGT with the *Telenoid R3* ($p < .05$). There was no between-group difference in entropy of N-grams among subjects.
Conclusion: These results suggest that RGT by tele-operated robot can promote communication in a way similar to that of human-facilitated RGT. We conclude that RGT using a tele-operated robot may increase communication opportunities for people who are unable to present to nursing facilities.

1. Introduction

Japan was first designated a super-aged society in 2007, with the percentage of the aged population having reached 27.7% in 2017. Due to super-aging and the declining birth rate, Japanese society now faces a critical labor shortage. This shortage is particularly evident in the nursing care sector where demand is expected to increase with the aging of society. In particular, the relationship between longevity and disability has led to projections of increased demand for long-term care service. The Ministry of Health, Law and Welfare (MHLW) estimates the number of dementia patients, combining those with vascular dementia and Alzheimer patients will be approximately 8 to 10 per cent of the over-65 population.[1] The Ministry of Economy Trade and Industry (METI) estimates that there will be a shortfall of 680,000 nursing care workers in 2035. However, a Survey on Labor Economy Trends (2015) showed that approximately 40% of the medical and care service facilities reported shortages of regular and part-time employees.[2] Furthermore, in the Tohoku area, staff shortages at hospitals were experienced after the Tsunamis and Radiation disaster, and remains unchanged.[3] Even though such a serious labor shortage existed, approximately 99,000 people had to resign from work for reasons associated with family caregiving in 2017.[4]

One of the government's main policies for coping with these constraints has been the development of robot technology to support long-term care. The Cabinet's "Japan Revitalization Strategy" of 2014 reported "A New Industrial Revolution Driven by Robots" to improve Japan's productivity, enhance the earning power of companies, and raise the remuneration of workers.[5] Regarding nursing care, both METI and MHLW formulated and revised a list of priorities to encourage ongoing contributions to promote self-reliance support.[6]

Under policies titled "Priority Areas to Which Robot Technology is to be Introduced in Nursing Care", the development of social robot for nursing-care, similar to Pepper, Paro and Nao, as well as wearable technological devices is progressing, together with evaluative research. However, the effectiveness of social communication robots in general has yet to be sufficiently demonstrated, as indicated by the fact that 80% of companies which had introduced Pepper in 2014, had terminated their rental contracts by 2018. One reported reason for this was that the original novelty of such robots had disappeared and that conversations with Pepper had become predictable and tedious.[7] Recently however, SoftBank has begun developing new software to enable Pepper to assist the rehabilitation and physical activities of older adults. It is therefore necessary to

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evaluate previous research so as to further improve robotic communication for persons with dementia (PWD) whose conversations may have a different focus from those of others in a real world context.

The research reports on social robots have focused mainly on Paro, a baby harp seal, AIBO, a robotic dog, and NeCoRo, a robotic cat, none of which are able to talk. The intervention research on therapeutic robots demonstrated specific effects on PWD in social interactions and decreases in psychological stress reactions measured by cortisol levels, electroencephalogram cortical neuron monitoring, and stress hormone ratios detected by urinalysis.[8]

We chose to use a tele-operated robot in our study because of its conversation capacity and applicability as a remote-operation system. As discussed above, a serious shortage of professionals and care workers is becoming evident. This shortage may result in a compromise in the quality of care service to such an extent that it no longer meets the PWD's social needs standards of communication, because care workers cannot provide sufficient time to engage in conversation with PWD. Professional support from remote areas via media such as the Internet, for example, would be more readily available if a tele-operated robot could be sufficiently improved so as to promote communication with PWD. Therefore, ongoing evaluative research into the role of tele-operated robots is of considerable importance.

A literature review of social robots for PWD published from 2005 to 2015 showed that most reported studies are of short duration, and have small sample sizes, while some do not involve actual robot usage, or are conducted in laboratories.[9] The literature reports research which examines the interaction of PWD with robots for an extended duration, in nursing facilities, but most of those findings were measured using subjective questionnaires, such as a face scale, interviews with staff, or increased activity levels, including visual, verbal, and physical interaction. Another literature review, published in 2019, summarized the effectiveness of social robots on outcomes (psychological, physiological, quality of life, or medications) of older adults from randomized controlled trials (RCTs). A total of 13 reports from 11 RCTs were identified from 2,204 articles, of which 9 studies were included in the meta-analysis. The range of the sample size varied from 18 to 415.[10] However, since the literature review did not make mention of reported studies on tele-operated robots, we have attempted to investigate and report this particular aspect of research in the field.

One difficulty in evaluating the effects of a tele-operated robot for PWD is that it is necessary to conduct a thorough linguistic analysis of the conversation or intervention, using appropriate quantitative data analysis. However, research in this area is still in a preliminary stage. One reported study which aimed to evaluate the effectiveness of a tele-operated human-like robot, Casper, a character-like robot Ed, and a tablet, was performed with 6 participants.[11] Another study on communication between persons on the autism spectrum and tele-operated robots was conducted with 2 participants,[12] while another study of a tele-operated human android robot was undertaken with 3 participants.[13] This was a unique comparative evaluation of a tele-operated robot, *Telenoid*, which aimed to clarify the difference between human communication and communication with a robot among PWD.[13] However, the findings were mainly measured by observation-based scales, and the number of words uttered was used as an objective indicator.

Based on the literature review, we propose that among tele-operated robots, *Telenoid* can provide a better opportunity for human-like conversation, as well as sensory stimulation, such as carrying a baby by holding it. We propose that using a *Telenoid* is preferable for promoting conversation with PWD, as well as reminiscence therapy. Reminiscence therapy is well-known and widely used to increase the opportunities for conversation of PWD, aiming to stimulate participant's brain function and social-interactive function.[14] Its effectiveness as a non-pharmacological evidence-based method of dementia management has been demonstrated.[15] The facilitation of both RGT and individual reminiscence therapy is supervised by a coordinator aiming to strengthen personal identity and coherence through the meaningful integration of past experience. Therefore, the coordinator, who is usually a psychologist or a social worker, plays an important role in RGT.

We were unable to find reported research which examined the effectiveness of the combined *Telenoid* and Reminiscence Group Therapy (RGT) approach. We were also unable to find comparisons of the contents of discourse between PWD and social robots, and the discourse between PWD and humans, using objective measurements. It remains to be shown whether PWD can communicate easily with a robot, and how the conversation with a robot differs from conversation with a human in RGT. The purpose of this study is to examine the effectiveness of tele-operated android robot reminiscence group therapy (RGT) for PWD, by comparing the efficacy of similar RGT with a human coordinator.

2. Method

A *Telenoid R3* (hereafter, *Telenoid*) tele-operated android robot was used for RGT for PWD in a nursing care setting (Figure 1). A tele-operation system can be implemented using only a single laptop. With an internet connection, *Telenoid* can be operated from any location, even across long distances. The operator's facial direction and lip movements are captured by a face recognition system and are remotely sent to the robot. Graphical User Interface (GUI) buttons control the specific movements of the arms and head to express the operator's behaviours and emotions, such as waving good-bye, or hugging. Unconscious motions such as breathing and blinking are generated automatically to give the illusion that the android is alive. RGT is delivered in a group setting in which all participants' comments can be used to help the participants to recall memories of past experiences.

We investigated six older adults (Average age 87.5, SD 4.50) who after hearing an explanation about the purpose of the study. Participant 5 (P5) had been diagnosed as having Alzheimer's disease, while the other five participants indicated a range of levels of cognitive deficit on their Mini Mental State Examination (MMSE) score, with an average score of 19 (Range, 27~13). The study complies with

Figure 1. *Telenoid R3*.

the Declaration of Helsinki, and was approved by the ethics committee of Waseda University with written informed consent obtained from each subject (Institutional Review Board: 2017-173).

The experiment was conducted at a public residential facility for seniors, to investigate the interactions of six older adults with dementia, with a tele-operated android robot, *Telenoid*. Experimenters divided the participants into two groups; the first group underwent three sessions of RGT with a human coordinator (c1), and the second group had three sessions with the same coordinator, through *Telenoid* (c2). After the first three sessions, the robot and the human coordinator were substituted in each group, and three more sessions were conducted.

All participants underwent six 20-minute sessions, from 11th July through 27th July in 2018. All six sessions were conducted using the same procedure. At the beginning of each session, the participants of the group were welcomed, starting with a self-introduction by the participants to probe their memory of names and social interaction, and then being informed about the theme to be addressed in each session. Materials were then distributed to the participants to assist their remembrance of the stories related to the topic of each session. (See Table 1). In order to avoid a carry-over effect, we avoided delivering two sessions with the same theme and material under c1 and c2.

We videotaped all sessions, and voice data for each participant was analyzed for the following features: Number of utterances, sentence final particles, and N-grams. The number of utterances refers to the number of words spoken by each participant. We also counted the number of sentence-final particles ("*yo*", "*ne*") using morphological analysis software, Mecab, for the Japanese language.[16] The frequency of sentence-final particles "*yo*", and "*ne*", which indicate softer expressions used in usual Japanese conversation, were also counted as indicators of natural and relaxed speech.[17,18]

N-grams of texts are extensively used in evaluating discourse and natural language processing tasks.[19,20] We calculated "entropy"[21] from 2-gram, 3-gram and 4-gram data using the following equation:

$$H(x) = -\sum_{i=1}^{n} p(x_i)\log p(x_i)$$

The term "entropy", first formulated in 1948, refers to the average amount of measurable-communicative-output information.[22] In physics, the word entropy is used frequently to refer to concepts such as "randomness", "irregularity", and "ambiguity". Information theory in discourse refers to exactly the same concept, and the more irregular the information, the more information regarding communicative complexity, or richness of discourse it carries, on average.[23]

This method, "entropy", is used to analyze linguistic data by evaluating experimental results. It has been used for many years to unravel the character of text and determine whether sentences are written by the same author. We used entropy as an indicator of discourse frequency under c1 and c2.

3. Results

P1, P2, and P5 showed a higher average number of utterances in c1, but significantly fewer in c2 ($p < 0.01$, $p < 0.05$, $p < 0.01$) (Table 2).

For sentence-final particles, P1, P2 and P5, showed a higher average number of occurrences in RGT under c1. ($p < 0.05$, $p < 0.05$, $p < 0.01$) (Table 3). However, P3, an 88-year-old-female participant (MMSE score 13) showed a significantly higher number of sentence-final particles, in discourse with the *Telenoid*, under c2 ($p < 0.05$).

There was no difference in entropy in discourse measurements of 2-gram, 3-gram and 4-gram between c1 and c2 among any of the participants (Table 4).

4. Discussion

This study is, to our knowledge, the first study of a comparison of RGT both with and without a tele-operated robot. The results suggest the potential of a *Telenoid* as an alternative to a human coordinator for GRT.

P5, an 86-year-old male participant (MMSE score 20) whose utterances decreased considerably in c2, was hearing impaired. He was unable to understand the robot's voice, and became confused during conversations under c2. His speech frequency did not increase under c2, even though he enjoyed RGT under c1. Therefore, an assessment of the special needs of participants should be a central consideration when using communication robots in nursing care settings. Also, for persons with hearing problems, the quality of the audio systems of *Telenoid* need to be improved considerably.

Table 2
Number of utterances under c1 and c2, and results of *t*-test.

Participant	c1	c2	*p*-value
	Average number ± SD	Average number ± SD	
P1	992.33 ± 159.90	348.00 ± 136.21	**
P2	1546.33 ± 202.33	623.67 ± 345.59	*
P3	175.67 ± 95.04	149.67 ± 60.04	
P4	669.33 ± 146.58	667.33 ± 327.64	
P5	1473.00 ± 405.63	190.33 ± 45.39	**
P6	719.00 ± 208.01	477.33 ± 165.05	

* $p < 0.05$, ** $p < 0.01$.

Table 3
Number of sentence-final particles under c1 and c2, and results of *t*-test.

Participant	c1	c2	*p*-value
	Average number ± SD	Average number ± SD	
P1	89.33 ± 30.29	24.67 ± 8.50	*
P2	73.33 ± 12.22	34.00 ± 20.88	*
P3	2.00 ± 1.00	9.33 ± 4.04	*
P4	40.00 ± 6.24	37.67 ± 13.65	
P5	59.67 ± 18.23	8.67 ± 5.03	**
P6	25.67 ± 10.97	23.33 ± 22.28	

* $p < 0.05$, ** $p < 0.01$.

Table 1
Contents of RGT sessions.

Session	Theme	Material	Group A	Group B
1	Memory of elementary school	Abacus	c1	c2
2	Memory of play	Juggling bags	c1	c2
3	Memory of food	Lunch box	c1	c2
4	Memory of home town	Mosquito incense	c2	c1
5	Memory of childhood and youth	Straw hat	c2	c1
6	Memory of festivals	Lantern	c2	c1

c1 = condition 1, c2 = condition 2.

Table 4
Entropy of participants under c1 and c2.

Participant	2-grams		3-grams		4-grams	
	c1	c2	c1	c2	c1	c2
P1	3.215067	3.219518	3.305043	3.187597	3.296741	3.158323
P2	3.219406	3.121886	3.169119	3.261274	3.298634	3.209021
P4	3.231491	3.273724	3.307762	3.220408	3.271679	3.290691
P5	3.261687	3.219092	3.278869	3.272906	3.212074	3.277613
P6	3.241816	3.287438	3.295896	3.214034	3.265351	3.220442

Further, more precise assessment of the need for special assistance will be necessary for persons with hearing problems, low vision, mindlessness, and somnolence during sessions of RGT when using robotic communication.

Since P1, P2, and P5 used many sentence-final particles under c1, but significantly fewer under c2, it is thought that they feel more relaxed under c1 compared with c2. In contrast, P3, who showed the least number of utterances in both conditions, showed a significant increase in sentence-final particles under c2. We assume that the reason why P3 didn't produce as much speech in c1 and c2 as other participants was not because of a lower level of cognitive function, since P1 and P6, who had the same level of cognitive function talked as much as the other participants did. It is thought that she felt more relaxed in conversation with *Telenoid R3*, (c2). Previous research has reported that older female adults tend to be relaxed when they interact with the *Telenoid*.[24]

Analysis of 2-gram, 3-gram and 4-gram speech for both c1 and c2 showed no difference in entropy in any of the six participants. There was no significant difference between the amount and variation of information, irrespective of whether the coordinator was a human facilitator (c1), or the tele-operated robot (c2).

A key concept in dementia care is to assist PWD to sustain communication and maintain a connection to family, caregivers and the environment. When PWD receive assuring communication from family and caregivers, they are more disposed to feel safe and secure in their environment. Further, behavioral psychological symptoms such as wandering, shouting, and problematic behavior may diminish as a consequence of the sense of comfort afforded by a safe environment. The shortage of caregivers, however, increases the work load of the caregivers thereby limiting their opportunity to have conversations with the residents in a facility for older adults. In particular, PWD may withdraw from human contact or set up other barriers to communication, resulting in apathy or depression among PWD. A meta-analytic review found that the influence of social isolation on risk for mortality is comparable with well-established risk factors for mortality.[25]

To prevent social isolation and loneliness of PWD, the use of a tele-operated robot as a coordinator of RGT, to stimulate communication, is proposed.

There are a number of limitations in the present research: First, the sample size is relatively small, and will need to be increased as research in this field progresses. Second, we were unable to compare the findings of our experimental group, with those of a control group. As research in this field becomes more consolidated, the effectiveness of RGT using a tele-operated robot will be confirmed by comparative studies.

5. Conclusions

It was expected that for PWD in RGT with a human coordinator, the human communication would have been preferred over that with a robot, and that it would have been more effective than that with a robot coordinator. However, the results indicate that among the participants, half (n = 3) could communicate with robots as well as they did with humans. Furthermore, some PWD may feel more comfortable when communicating with a robot. We consider RGT with a tele-operated robot to have potential for increasing communication opportunities for people including PWD's family and friends, who are unable to attend such opportunities at nursing facilities.

Conflict of interest

All authors declare no conflict of interest.

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