Effects of robot-assisted activity using a communication robot in elderly individuals

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Abstract: Robot-assisted activity (RAA) is a countermeasure for mental health problems among the elderly by providing pleasure and relaxation through interaction with robots. To clarify the immediate effects of RAA with a communication robot on elderly people. This study included 12 elderly women with no orthopedic or nervous system disorders, motor deficits, or sensory disorders. Participants received 5 minutes of RAA using a communication robot, and their neurophysiological indices were assessed. Emotions and mood states were measured following RAA. Moreover, resting-state EEG activity as indicated by alpha power, beta power, and the relative power index (alpha/beta) was assessed on Fz and Pz before and after RAA. Our results demonstrate that participants felt more positive emotions and mood states, such as “warm” and “fun,” after RAA. However, the resting-state brain activity of the participants did not change after RAA. This study suggests that RAA with a communication robot modulates psychological factors in elderly women. Thus, RAA with a communication robot may be useful in supporting the mental health of elderly women.

Key words: Communication, Electroencephalogram, Robot Assisted Activity

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I. Introduction

The average age of the Japanese population is increasing annually¹⁾. Many individuals experience loneliness and depression as they age, either as a result of living alone or the loss of contact with family and friends²⁾. Mental health conditions are significant causes of morbidity³⁾ and mortality in elderly individuals⁴⁾. In general, women are at a higher risk of developing mental illness than men⁵⁾. Therefore, the prevention of the decline in mental health among the elderly women is important.

Robot-assisted activity (RAA) is a countermeasure for mental health problems among the elderly⁶⁾. RAA was proposed and developed by Shibata⁷⁾ for the purpose of providing pleasure and relaxation through interaction with robots⁸⁾. RAA has evolved from animal-assisted therapy, since robots have the advantage of being free from the risks of animal allergies, infections, bites, and wounds⁷⁾. Robots used in RAA include an alternative pet type⁹⁾ that induces attachment by moving and crying, a recreational type¹⁰⁾ that performs gymnastics and quizzes, and a communication type¹¹⁾ that verbally communicates with the target individual. Previous studies have reported that RAA improves the quality of life (QOL), relationships, mood, and loneliness in the elderly^{9, 12, 13)}.

Daily communication is an important element of the mental health of the elderly¹⁴⁾. However, opportunities for communication decrease with age owing to increased social isolation¹⁵⁾. Therefore, communication robots have been developed and are currently being used in RAA as an alternative means of providing communication opportunities to the elderly¹⁶⁾. There are numerous reports on the effects of RAA with alternative pet-type^{17–21)} and recreational robots^{22–24)}, but there have been few reports on the effects of RAA using communication-type robots^{16, 17)}. Because communication opportunities are important for the mental health of the elderly, it is necessary to clarify the effects of communication robots on mental health.

Moreover, although the effects of RAA are often studied from a neuropsychological perspective^{16, 17, 20–22, 24)}, few have been studied from a neurophysiological perspective^{18, 19, 23)}. Electroencephalogra-

phy (EEG) can be used to determine a neurophysiological index, has high temporal resolution, and is suitable for detecting immediate changes caused by RAA. In addition, previous EEG studies have clarified the brain areas that are activated in response to changes in emotions and moods^{25, 26)}. Therefore, EEG can be used as an objective index to support changes in subjective emotions and moods observed owing to the effects of RAA.

Our research questions were “whether RAA using a communication robot has an effect on elderly women” and “what neurophysiological changes are behind the effect.” Thus, the purpose of this study was to elucidate the immediate effects of RAA with a communication robot on elderly women using EEG as a neurophysiological index.

II. Materials and Methods

This study included 12 elderly women (mean age, 81.2 ± 7.3 years; mean height, 147.4 ± 4.1 cm; mean weight, 51.5 ± 8.1 kg; Mini-Mental State Examination score, 27.7 ± 2.1 points) with no orthopedic or neurological disorders, motor deficits, or sensory disorders. The scope and contents of this study, as well as the precautions against the disclosure of personal information, were explained to the participants verbally and in written form, in accordance with the tenets of the Declaration of Helsinki. Participants provided written informed consent by signing the relevant documents before participation in this study.

Participants received 5 minutes of RAA while sitting in a chair with a backrest. RAA was performed using Chapit (Ray Tron Inc., Osaka, Japan), a communication robot with the appearance of a stuffed toy, equipped with a speech recognition system. Chapit responds when it recognizes a predetermined phrase by vocalizing in a manner that mimics the manner of speaking of a 5-year-old boy (a one-way conversation in which participants speak and Chapit responds). Moreover, Chapit can perform recreational activities such as prefecture quizzes, arithmetic operations, memorization games, and singing.

Participants were given the Chapit and a list of established phrases on paper (e.g. “Good morning,”

“What time is it?”, and “Please say something interesting”). Subsequently, the researcher read aloud from a short script: “This is Chapit. Chapit is a communication robot. Chapit will respond when you talk to Chapit. Let us start talking with Chapit using words from the phrase list.”

Emotions and mood states were assessed after RAA, and resting-state EEG activity was measured before and after RAA.

Emotions and mood states were assessed after the RAA session. A 5-point scale developed with reference to a prior research questionnaire²⁷⁾ and the Likert scale²⁸⁾ (1=strongly disagree to 5=strongly agree; higher scores indicated positive emotions and mood states) was used to measure the degree to which participants felt warm, felt enjoyment, and felt a sense of task accomplishment (i.e., spoke well with the robot).

Resting-state EEG activity before and after RAA was measured for 120 s in the “eyes open” condition, while the patients were seated in a chair with a backrest. The EEG was obtained with an electroencephalograph (Discovery 24 E, BrainMaster Technologies Inc., Bedford, USA) and an active dry electrode system (Miyuki Giken Co., Ltd., Tokyo, Japan). The EEG was recorded with 2 channels (Pz and Fz) based on the International 10-20 system at a sampling rate of 256 Hz. Reference electrodes were attached to both earlobes.

The recorded EEG data were processed using the Brain Vision Analyzer 2.0 commercial software (MES, Munich, Germany) as follows: the band pass filter was set to 1-40 Hz and segmented into a 2-s-long epoch. Subsequently, fast Fourier transformations (FFT) were used to calculate the EEG power for each epoch. Alpha (9-13 Hz) power and beta (13-20 Hz) power, obtained from the FFT spectra, were averaged over trials for each participant, electrode (Pz, Fz), and measurement period (pre, post). The alpha wave reflects physical and mental relaxation with awareness of the surroundings, and the beta frequency band predominates in states of attention, concentration, anxious thoughts, tension, and fear²⁹⁾. The state of each participant’s emotional response was calculated as the relative power index (alpha/beta)³⁰⁾. The relative power

Table 1. Medians and value ranges of emotions and mood states after robot-assisted activity.

	Value
Warm (scores)	4.5 (3-5)
Fun (scores)	5 (3-5)
A sense of task accomplishment (scores)	3 (2-5)

Presented as median (minimum-maximum).

index provides a quantification value of the balance between neural correlates of a relaxed/focused mindset and those of an overactive/agitated mindset³¹⁾.

The Shapiro-Wilk Test was used to test for normality of the distribution. The paired t-test and Wilcoxon signed-rank test were used to compare pre- and post-EEG indices. Statistical analyses were performed with SPSS ver.24.0 (IBM, Chicago, IL, USA). P-values <0.05 were deemed to be significant.

III. Results

The degree to which participants felt “warm” and “fun” after RAA was above median. Alternatively, half of the participants indicated neutral feelings, with respect to the degree of a sense of task accomplishment (Table 1).

The FFT analysis was performed on the EEG data of each measurement period and electrode to calculate the alpha and beta band frequency spectrum. The effects of RAA on the alpha power, beta power, and relative power index (alpha/beta) on both Pz and Fz are presented in Tables 2 and 3. There were no significant differences between the measurement periods for any items in Pz and Fz ($p>0.05$).

IV. Discussion

This study clarified the immediate effects of RAA on the elderly women using a communication robot. The emotional and mood states after RAA and the resting state brain activity before and after RAA were measured. The results of this study indicated that elderly individuals experienced more positive emotions and mood states after RAA and that there was no change in resting state brain activity after RAA. Our findings indicate that RAA with communication robots may improve the psychological state of

Table 2. Means and standard deviations of three main EEG indices for each period at Pz.

Variable	Pre	Post	Degree of freedom	Effect size (r)	p-value
α (μ V)	60.18 (22.02)	60.13 (31.63)	11	0.00	0.99
β (μ V)	117.36 (53.23)	110.24 (53.06)	11	-0.34	0.24*
α/β	0.53 (0.12)	0.55 (0.17)	11	0.17	0.57

Presented as mean (standard deviation).

Paired t-test.

*: Wilcoxon signed-rank test.

Table 3. Means and standard deviations of three main EEG indices for each period at Fz.

Variable	Pre	Post	Degree of freedom	Effect size (r)	p-value
α (μ V)	56.90 (31.22)	52.66 (14.97)	11	-0.02	0.94*
β (μ V)	129.29 (102.71)	108.52 (25.83)	11	-0.16	0.58*
α/β	0.48 (0.14)	0.50 (0.14)	11	0.19	0.53

Presented as mean (standard deviation).

Paired t-test.

*: Wilcoxon signed-rank test.

elderly women.

The participants of this study reported that they felt “warm” and “fun” to a higher degree after RAA. According to a previous study²⁷⁾, healthy elderly individuals have a positive impression (approximately 4.2 to 4.3 on a five-step Likert scale) of RAA with alternative pet robots. The participants in this study also experienced positive emotions ($m=4$ on a five-step Likert scale) after RAA with a communication robot. Therefore, RAA using a communication robot is considered to be a means of promoting positive emotions among the elderly.

In contrast to the results for emotional and mood states, the participants indicated that they “neither agree nor disagree” ($m=3$ on a five-step Likert scale) for the item “a sense of task accomplishment (spoke well with the robot).” In this study, a conversation between the participant and the communication robot using fixed phrases selected from the phrase list was necessary. Moreover, in some instances, the robot failed to recognize the participant’s speech and did not respond. As a result, natural and fluent conversations with communication robots were difficult, which may have caused the participants to feel uncomfortable with the unnatural feel of the communication. Improvements to the communication robot software to address uncertainties and external disturbances (e.g.,

combining the Kalman filters³²⁾ or using an improved particle filter³³⁾) should allow for more natural conversations in the future.

Furthermore, the EEG indices for both Pz and Fz did not change significantly before and after the RAA. These results suggest that RAA did not alter the emotion or mood state of elderly women at the neurophysiological level. This result is probably due to the low stimulation intensity of the RAA. Future studies will need to be revisited with modifications such as extending the implementation time of the RAA and changing the content of the robot’s conversation. In addition, the values of the relative power index (alpha/beta) in this study ranged from 0.48 to 0.55 on average, which was much smaller than the reported value of 2.83 ± 1.80 in the previous study³¹⁾. This difference in measurement values was likely influenced by differences in measurement conditions (EEG was recorded at closed eye rest in the previous study³¹⁾). In future studies, it is necessary to compare the measurement conditions with those of the previous studies.

This study had some limitations. First, gender-based biases may exist because all the participants were women. Therefore, it is necessary to verify whether similar results would be observed amongst men. Second, the sample size of this study was small, and our results should be interpreted with caution. Subsequent

studies with a larger sample size are required to confirm our findings. Third, it is possible that the emotions are altered by the specific interest and concern of talking to the robot. Future studies need to use comparisons with control conditions, such as using human children as the target of conversation. Fourth, the psychological index used in this study was a questionnaire developed with reference to previous studies. Future studies will need measurements based on well-established and appropriate psychometric indicators. Finally, the long-term effects of RAA and its effects on individuals with cognitive decline remain unclear. This study was proof of concept, in that it showed that there were no harmful effects of RAA. This lays the foundation for larger and more rigorous studies on the long-term effects of RAA on mood.

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