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Behavioral Responses of Nursing Home Residents to a Robotic Pet Dog with a Customizable Interactive Kit

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Abstract

Robot therapy for the elderly had been a novel advent for the past decade and the efficacy of such therapeutic procedures had similar benefits to pets in improving health outcomes. But there had been experiments which resulted in showing the loss of interest over time due to limited levels of interaction. This paper regards that if a collection of customizable interactive games comes along with the robotic pet dog, the long-term interest will sustain and in effect, long-term psychological benefits would be rendered. Here in this study, we investigate the effect of elderly interacting with pet robot thought multimodal peripheral devices with a different level of cognitive challenges using questionnaire, facial temperature, EMG and EEG.

Keywords: human-robot interaction; elderly care; robotic therapy; behavioral assessment

1. Introduction

Extensive research has been undertaken around the world towards the use of robot therapy to treat loneliness, depression and dementia in elderly patients. The presence of pet robots can reduce stress and improve health outcomes and robotic animals can be as effective as real animals [1, 2, 3, and 4]. It has been shown that the elderly with dementia are attracted to robots, raising the promise that appropriately designed robots with an interactive stimulation features could play an important role in their treatment [5].

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Abbreviations

MAV	Mean Absolute value
AS	Time taken in secs for 10 cycles using Dumbbell integrated with ActSense
SW	Time taken in secs for 10 cycles using Standard Weight without ActSense

There are many research studies done to show how pet robots are helpful during therapy among elderly and how acceptance is measured [6]. Seal like therapeutic robots for instance PARO [7], are been widely used in nursing homes. Several healthcare robots like AIBO a dog like robot, NeCoRo a cat like robot, PARO a seal like robot are developed, however, not all are well accepted due to various expectations from the range of stakeholders [8,9,10,11]. In robot therapy, people feelings has to be stimulated through interactions and interest to engage with pet robots has to be sustained for long term therapies. For pet robots, shapes, feeling of touch (texture), response mimicking animals has to be carefully designed. A single perfect design which will be accepted by the elderly is unlikely. Robots used for cognitive training should engender mental effects, such as comfort, pleasure and relaxation. Actions that manifest themselves during interactions with elderly can be interpreted as if the robots had hearts and feelings [12].

After carefully accessing individual needs and preferences we are proposing a customizable therapeutic pet robot kit. The kit will allow robot's functionality to be modified or extended based on the individual needs and thereby enable greater acceptance. By using 'user matching strategy' robots are matched to human expectation. The quality and quantitative study aimed to access response of elderly people to the dog robot, SNOWY, in an elderly home setting.

2. Experimental Design

The study was conducted at Lions home for elderly, Singapore. Residents capable of completing the study by staff were approached and informed about the trial. 12 residents were recruited for the study. The researcher asked residents to make themselves comfortable and rest for ten minutes. The initial facial thermography reading was taken. Residents were briefed about the study and wireless EMG and EEG sensors are connected. The researcher brought SNOWY into the room and turned it on. He placed SNOWY on a table in front of them so they could cuddle it. He explained how to interact with SNOWY using ActSense (an interactive dumbbell), glove and how to play game using reminiscence and music therapy kit. More details of the interactive kit is described in Fig. 1.

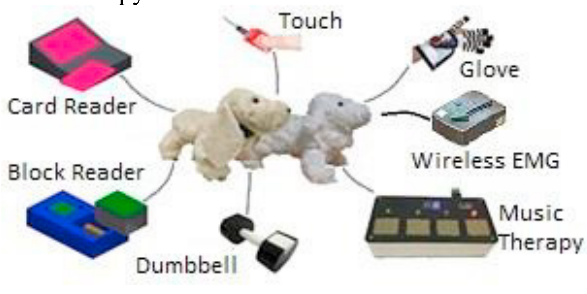

Fig. 1. Complete set of interactive therapeutic pet robot kit

The measurement criteria for the reaction of the subjects were in the form of EEG & EMG data evaluation, face score, a holistic questionnaire and thermal activity levels before and after interaction analysis. The experiment was to be run with 12 elderlies with age ranging from 65-91. Subjects were all females. One set of SNOWY was introduced and the interaction sequence of each device is in the order of the dumbbell, the card game, the glove and the memory game. The interaction time would be 10 minutes per elderly. They were not subjected into the same room together. A different chamber was assembled for the solo interaction with the kit and to avoid influences from their peers. For statistical convenience each 10-minute interaction is termed as an event.

3. Intervention - Study

3.1. A 4-phasal approach

The first phase is the interaction solely with the ActSense and dumbbell inside. EMG electrodes are placed on the arm holding the holding the dumbbell or ActSense. The first minute consist of the user to move the ActSense across Z-axis (bicep curl) which triggers SNOWY to move up and down – like a regular squatting up and down movement. The second minute consists of moving across the Y-axis which makes SNOWY to walk toward the user. The experimental ActSense weighs around 1Kg. EMG readings are recorded. The same procedure is followed with dumbbell which weights 1kg. EMG data is recorded.

Following the ActSense interaction, the users move on to more of a mental exercise which enables the dementia prone patients – matching card game. The game is divided into two parts as mentioned in the technical aspect section, so we take turns on the color and picture matching sessions – at times based on how the elderly did on the color test we move onto the picture test otherwise we did not. During the game resident EEG is measured.

The third phase is the glove interaction – again moving back to a physical exercising peripheral which enables frequent metacarpal movements for arthritis patients in these nursing homes. For the final phase we move toward another psychological exercise in the form of the memory game. As mentioned each of phase had EEG on at all times and for the dumbbell EMG was put on. Video recording was taken to investigate on the facial changes (to track emotion before and after an event) and a thermal camera to track the activity profile during the interaction. The fourth phase is a questionnaire that was conducted right after the experiment.

4. Results

4.1. Face Score

To comprehend the reactions from interaction level face scores were introduced – 1 being the happiest/most positive and 7 being the most negative as shown in Fig. 2[13]. The first face score test was applied 1 week before the elderlies were exposed to SNOWY. The subsequent face scores were before and after the event. The face scores were being run and recorded for all the 12 residents as shown in the Fig. 3.

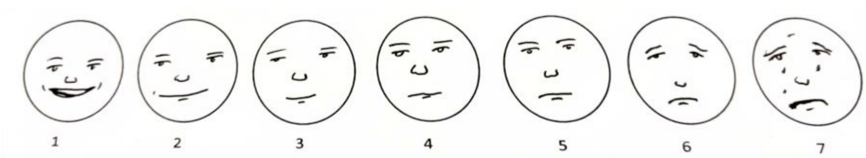

Fig. 2. The face scores are determined from 1 being the happiest and 7 being the saddest

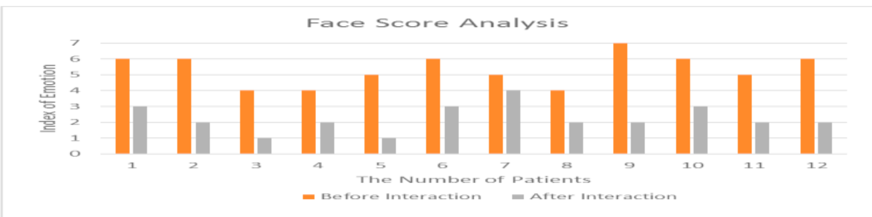

Fig. 3. Emotion Index across four weeks of interaction and 1 day few weeks before as control

The face scores were considerably on the good scale. Initial testing with the holistic kit ran on the users had a significantly positive outcome but the valid measurement scales for predicting user acceptance of the entire kit is under subject of scientific inquiry. More concrete experimentation was thereafter conducted using EEG for involvement.

4.2. Questionnaire

At the end of interaction with SNOWY the following question has put forth and the observation has been recorded. Studies suggest that the quality of responses from the elderly may be less than that for other respondents [14], hence the questions are kept simple and straightforward as shown in Table 1. Insights on the questionnaire had been extremely positive and design suggestions had been key for further engineering iterations.

Table 1. Basic attribute of 12 elderly people

Question	N out of 12	Percentage
Scale of 1-5 how much they liked SNOWY		
5	11	83
4	1	17
Can SNOWY help in daily life		
Yes	12	100
Can SNOWY do things better/more features?		
Yes	1	17
No (no need)	11	83
Useful for daily life?		
Yes	12	100
The games were:		
Easy	9	75
Difficult	3	25
Would you spend time with SNOWY?		
Yes	12	100
More games?		
Yes	5	42
No	7	58
How about if SNOWY talked like a person?		
Yes	10	83
No	2	17
Colors for SNOWY?		
Brown	7	42
White	5	58
Is SNOWY too big?		
Yes	0	-
No	12	100
Any problems when interacting with SNOWY?		
Yes	4	33
No	8	67
Would you like to take SNOWY back home?		
Yes	11	83
No	1	17

4.3. Electroencephalography (EEG) – Engagement Studies

Recent theories in the field of neuroscience propose that emotions play an essential part in our cognitive processes and decision making. The EEG device for evaluation on this setup was NeuroSky MindWave Mobile BrainWave Kit. The headset has an embedded BT/BLE dual module that helps in compatibility with PC. For this experiment beta waves (12-38 Hz) were noted on the scale of time. The rationale behind beta was to gauge the amount of attention the residents had over the interactive period of time since that frequency of the brainwave denotes the waking state of consciousness. The state is when the attention is directed for cognitive tasks such as each of the peripheral devices that engage them in a form of game [15, 16].

The results were the averages of the beta activity of one resident who underwent all the interactive devices. As it can be inferred from scatter plot from Fig. 4, the glove and the dumbbell had the most condensed number of peaks – this corresponds to the fact SNOWY has the most activities like sitting, dancing, squatting and walking based on those two devices. The other games which are more of psychological exercises counterintuitively had lower beta activity which would suggest that their attention is higher when SNOWY is more active. Music therapy was the most mentally taxing of the games and had the lowest attention rate as SNOWY has only one activity of indicating if a pattern is correct or incorrect. From the repeated measure analyses of Beta Wave for all the interaction activity with 12 elderly residents, the statistics indicate an upward trend when elderly interact or engage with SNOWY.

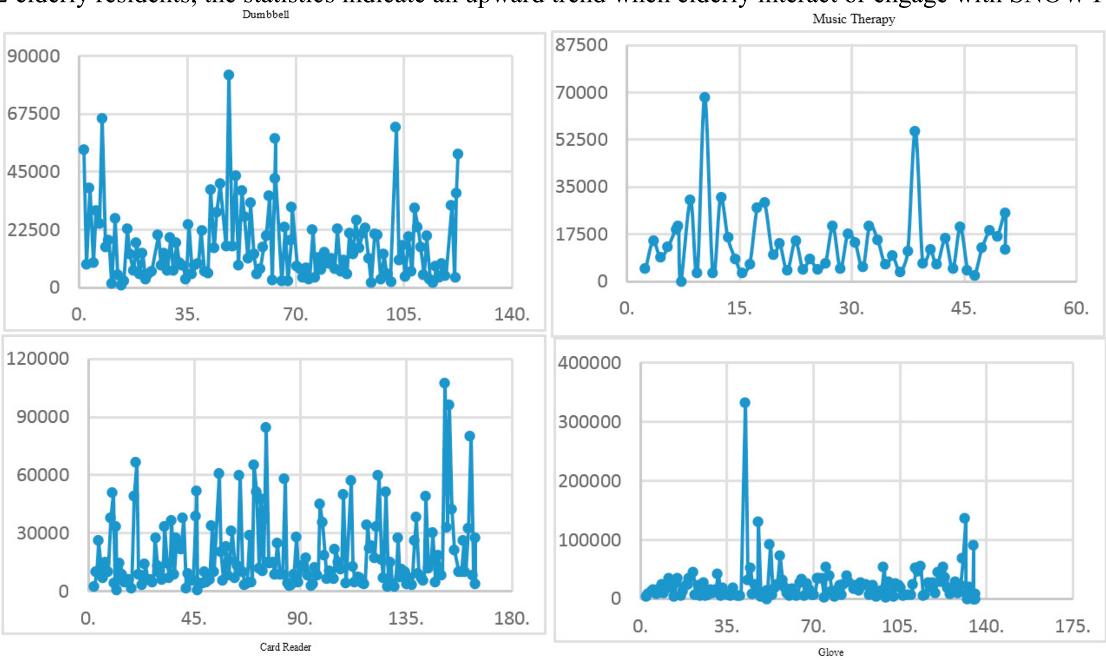

Fig. 4. Beta Wave Scale in Y axis and Time in X axis (Sec)

4.4. Electromyography (EMG)

The objective of this electromyography study is to validate the efficacy of this interactive Pet therapy for selected elderly subjects. This involves elderly controlling the robot movement through predefined task using dumbbell integrated with and without of an ActSense module. The task is to flex the elbow by holding the dumbbell in hand, followed by supination / pronation of the fore arm and to control the robot movements. If the dumbbell has integrated ActSense, the robot will either sit or stand and walk forward controlled by the arm movements of the elderly in order to enable elderly to actively engage in the designed task. Further, the designed task is involved with the flexion of elbow which is activated by the contraction of muscle Biceps brachii, which is triggered by an electrical signal sent by the brain. Similarly, the supination or pronation of forearm is accomplished by the contraction of pronator teres muscle in the same way as the biceps muscle. This process is the same for all the muscles that involved in performing any functional tasks. Recording of these electrical activities of any muscle movement is known as electromyography and the data obtained is called electromyogram or EMG that represents compound muscle action potential and often used as an information about neural activation of muscle [17]. EMG is used to understand the muscle's activities and employed as a tool to analyze muscle activities [18] while performing a designed functional task.

Data from EMG and three axes accelerometer are acquired using Delays' TrignoTM wireless EMG system - a 16-channel wireless EMG acquisition system with its wearable TrignoTM snap on lead sensor. These sensors will acquire EMG and three axis accelerometer data and transmit wirelessly to the EMG base station connected to PC. Installed EMG works acquisition software will record the data into PC Hard disk drive. Each subject is asked to flex their elbow followed by supination / pronation of the fore arm 10 times and the EMG with acceleration data were collected using Dumbbell with and without ActSense. The raw EMG were processed using the Delsys EMGWorks Analysis software.

The EMG data were first rectified to eliminate negative peaks. Afterwards, the mean absolute value was estimated. Each channel data were analyzed for Dumbbell with and without ActSense. Active interaction of the exercise with the robot is determined by the time taken to complete 10 cycles of flexion and pronation were calculated from the processed EMG data. MAV of EMG from Biceps Brachii (EMG1) and pronator teres (EMG2) are shown in Fig. 5.

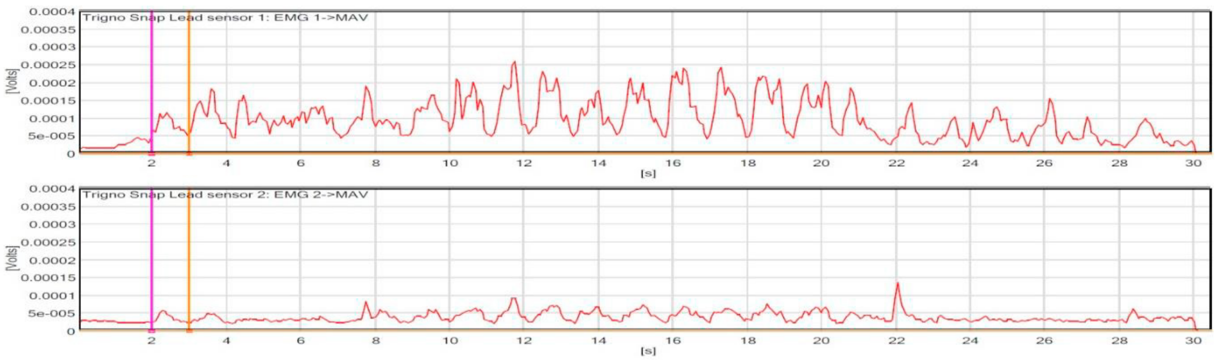

Fig. 5. Processed EMG of a subject captured from Biceps Brachii and Pronator Teres with ActSense

The results were tabulated and plotted to compare them with and without ActSense. In the X-axis EMG1 and EMG2 represents Mean Absolute Value (MAV) of the EMG from Biceps Brachii and Pronator Teres muscles respectively. Each subject has processed data namely EMG1 and EMG2. All 12 elderly subjects' data were compiled and plotted. The data is tabulated as shown in Table 2, further has been plotted as bar chart as depicted in Fig. 6.

Table 2. Time Taken to complete 10 cycles of Flexion and Pronation of Upper Limb - in Secs

	Sub 1		Sub 2		Sub3		Sub 4		Sub 5		Sub 6		Sub 7		Sub 8		Sub 9		Sub 10		Sub 11	
	AS	SW	AS	SW	AS	SW	AS	SW	AS	SW	AS	SW	AS	SW	AS	SW	AS	SW	AS	SW	AS	SW
EMG1	14	17	13.5	18	19	26	14	19	13.5	15	14	16.5	16	18	11	14	16	18	13	13.5	13	17
EMG2	14	16.7	13.7	18	18.8	26	13.8	19.1	13.7	15	14	16.5	16.2	18.1	11	15	13	14	12	12.5	13	15

From the data, it is clear that almost every subject has completed the task using the Dumbbell with ActSense in lesser time compared to Dumbbell without ActSense, which clearly indicates that elderlies are motivated when interacting with the pet robot. EMG data reveals that their muscle activity during the movements corresponding to the task that is they are motivated in performing the functional tasks which improves the outcome of the therapy procedures when engaged pet robot therapy.

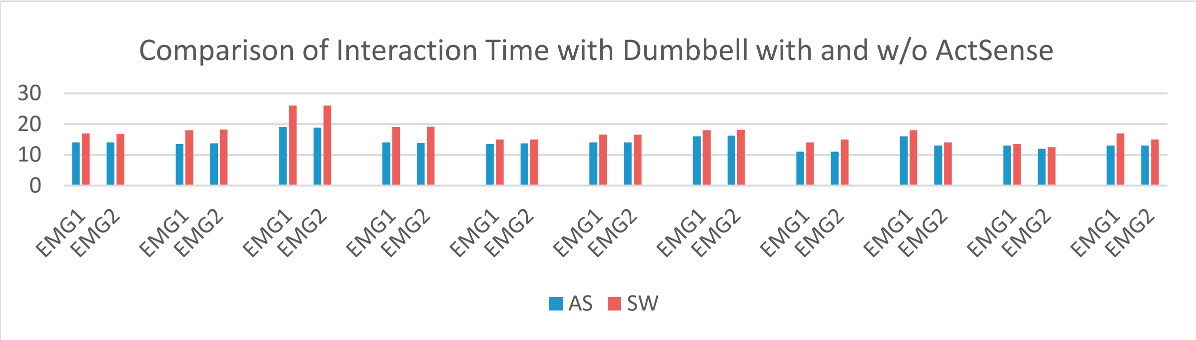

Fig. 6. Interaction time with Pet Robot using Dumbbell with ActSense and without ActSense

4.5. Thermal Score

Neuroscience plays an essential part in our cognitive processes and decision making. Change in skin temperature may also reflect a change in the affective status [19, 20]. With the help of using a thermal imaging camera, we are able to do capture the forehead temperature of elderly residents before and after interaction with Snowy and its peripherals. Below is an example of the thermal imaging with the resident from the Lion Befrienders Fig. 5. Table 3 shows the fore head Maximum temperature, before and after interaction with pet robot.

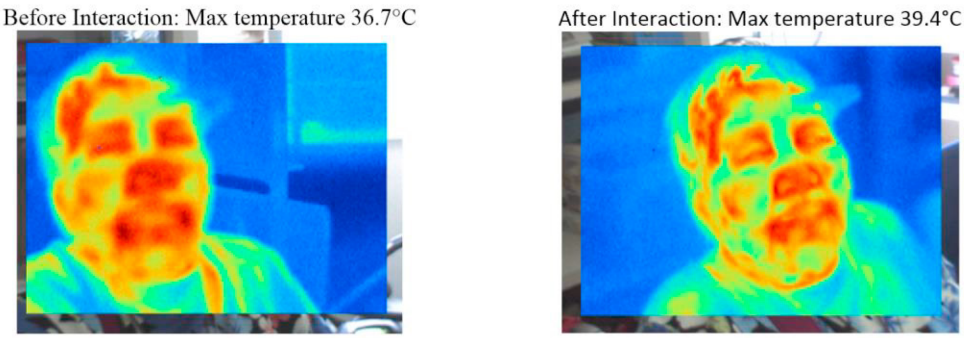

Fig. 7. Interaction time with Pet Robot using Dumbbell with ActSense and without ActSense

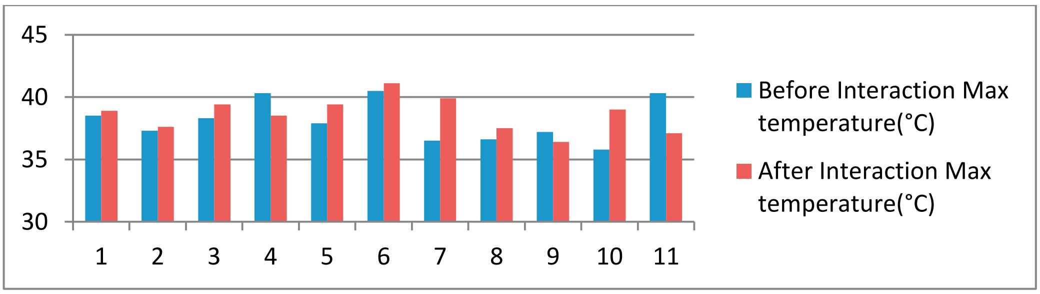

Fig. 8. Tabulated Resident Facial Temperature Results

5. Conclusion

The pilot study found that interacting with therapeutic pet robot has found to be beneficial. In the current research, it was noted that many residents were happy and relaxed when they were with pet robot and the survey from the questionnaire proves it. There has been increase in facial forehead temperature immediately after the interaction. This could be because of significant activations around the pre-motor area and the supplementary motor area. The results from the EMG data has proven elderly engagement has been increased during exercise when using pet robot. For cognitive assessment EEG data indicates an increased Beta wave which corresponds to active involvement whenever elderly uses peripheral devices to engage pet robot. The study has found that pet robots may have physiological health benefits. However, this was a trial study conducted with a small sample size to establish our initial findings. Future research should aim to build on these findings to explore the health effects of pet robot over a longer period of time with our customizable interactive kit.

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