An Investigation of User Perception and Behavior for Robotic Exercise Coach on Different Age Groups

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Abstract
With the advancement of robot technology, service robots for home use have gradually entered people's daily life. However, what is the acceptance and expectation from people for such innovative products and services? Will it be different among different family members of different ages? This study aims to compare the user perception and behavior on robotic exercise coach among different age groups through experimental design. By applying the Wizard of Oz method in the experiment, 100 participants of different age groups were recruited and instructed to interact with a robotic exercise coach, which was remotely controlled by one of our researchers. The researchers recorded the experiment and evaluated the performance of each participant during the experiment. After each session, a five-point likert scale questionnaire was used to collect the participant's subjective ratings on the interaction with the robot. Finally, through statistical analysis of experimental data the influence of user's age on the robot interaction was inspected; in addition, suggestions for the robot interaction design for users of different ages for the future were also proposed.

Keywords**:** Human-robot interaction, Embodiment, Exercise coach, Wizard of Oz method

Introduction

The time of intelligent robots has come, are we ready for that? Ericsson Consumer Lab (2014) had included "Internet Expected Everywhere" and "Domestic Robots" in its 10 Hot Consumer Trends reports for the years 2015-2020. This suggests that the business circles are optimistic about the business opportunities arising from the application of hi-tech for promoting human health and improving quality of life. For example, the Pepper (Figure 1), a robot developed by Soft Bank, has been so far widely used in stores and exhibition halls. Consumers can communicate with this robot through language and limbs movement. The Pepper has on its chest a touch screen with which people can set up the robot for such jobs as entertaining customers, presenting products, and interacting with consumers.

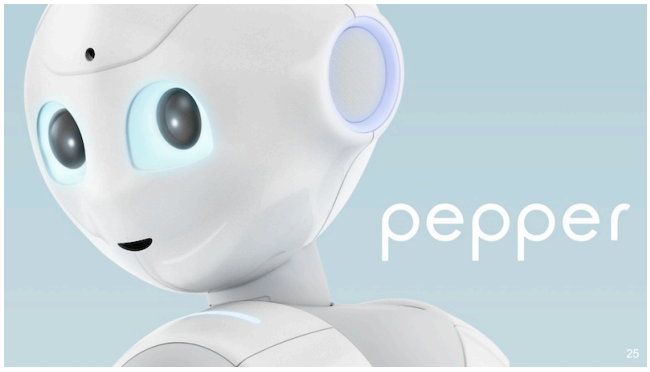

Figure 1: The Pepper

In recent years, the interaction between humankind and robots has been making progress all the time. In scientific studies, Human-Robot Interaction(HRI) has gone beyond industrial applications to applications in the service sector (Cynthia, 2000). Robots have been used more and more in daily life, including elderly care, medical care, babysitting, and education (Fong, Nourbakhsh & Dautenhahn, 2003). Their application mode varies in different fields. It is a trend for future research whether robots can be put up with and accepted by all family members. In a study by Powers, Kiesler, Fussell & Torrey (2007), physical and virtual robots served the role of health adviser and interacted with subjects. The study results showed physical robots left more positive social feel to the subjects than virtual robots did. In light of the above-mentioned studies, the perception left on and the behaviors provoked in the subjects by HRI of physical robots are a topic worth exploration in HRI research field.

According to a study by Syrdal (2015), which probed into the perception left and behaviors provoked in human subjects by HRI in specific scenarios, the establishment of an interaction scheme is indispensable for HRI. The experiment attempted to identify potential users and corresponding interaction schemes and revealed that during the early development stage of prototype, it is possible to identify potential users and interaction schemes by scenario setting and conditional experiments. In light of that, this study establishes a health coach robot that is capable of providing health information service, in order to determine whether it will leave different perception and provoke different behaviors in subjects of different age groups by virtue of interactive schemes for health consultation.

Related Works

Fong et al. (2003) in their study of Socially Interactive Robots argued that a social robot is similar to our colleagues, partners, and assistants, which means it has to be capable of receive information from human or the environment and make social response in an interactive scenario. The study also mentioned that social robots have to be provided with better social sensing module.

Cory (2008) in a study of health advisor robots investigated the long-term interaction between human and a robot that can provide weight reduction consultation and take records. The results indicated that the subjects preferred the interaction with the Autom(Figure 2), a physical robot, over the interaction with a computer agent and via paper logs.

Matsusaka (2009) investigated the TAIZO (Figure 3), a rehabilitation and exercise robot which demonstrated physical exercises in various operation modes in collaboration with a human demonstrator, and determined whether there was any significant difference in subjects' operation mistakes/fulfillment; opinions on the robot's ease of use, enjoyment, expectation; and willingness to use the robot. It is a research direction of our future studies to determine whether robots can deliver better service and feeling in the field of health.

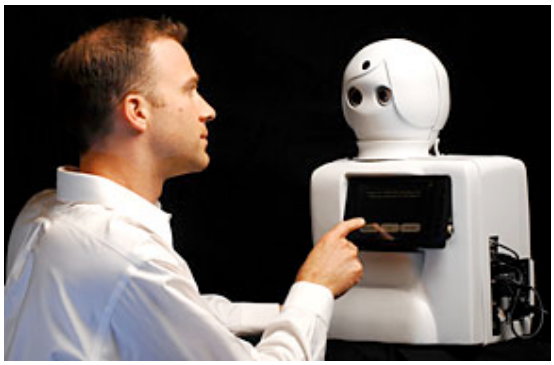

Figure 2. The Autom Robot

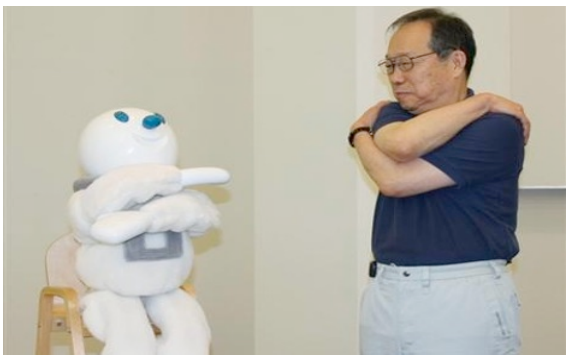

Figure 3. The TAIZO Robot

Wizard of Oz method has been used in experiments that involve prospective technology to evaluate subjects' behavioral response to the technology as an attempt to identify potential users and application scenarios for the technology (Dautenhahn, 2014). The subjects during such experiments may feel that the robot is autonomous, but in fact it is controlled by the experimenter. Fasola & Matarić (2013) in their experiment used the Wizard of Oz method to explore the interaction between a health coach robot and senior subjects and to help them do exercises.

Unified Theory of Acceptance and Use of Technology (UTAUT) scale was originally proposed by Venkatesh (2003) for determining whether a technology product is acceptable in its working environment by people. Later, Heerink (2010) proposed a modified UTAUT scale and used it to determine whether a social robot would be accepted by seniors. The original and the modified scales were compared and it was found that in addition to the items of the original UTAUT scale for use in working environment, several items, including faith, perceived enjoyment, perceived sociability, perceived adaptability, and social presence, had to be added to the

modified scale, in order to determine the acceptability of the robot in seniors.

Methodology

This study aims to investigate the interactive behaviors and emotions of users of a health coach robot in different age groups. The experiment was carried out in two stages and subjects were divided into 4 age groups. The first stage involved health consultation tasks and the second stage involved limbs coordination exercise tasks. Once both tasks had been completed, the subjects would be requested to complete the scale and take an interview.

1. Variables of the study and design of the scale

The control variable in this experiment design was the subjects' age groups. There were 4 age groups, i.e. Youth (aged 18-27), Mature (aged 28-38), Middle-aged (aged 39-49), Senior (aged 50 or above). Dependent variables were measured with the modified UTAUT scale of Heerink (2010) and a self-subjective scale developed by Powers (2007), in which the subjects' subjective feeling was divided into two aspects, *Psychological/Emotional Status* and *Attitude towards the Physical Robot*. The two aspects were subdivided into 10 factors(see Table 1), i.e. anxiety, perceive ease of use, response attitude, perceived enjoyment, perceived sociability, perceived adaptability, perceived usefullness, social influence, social presence, and Trust, and designed into a 5-point Likert scale.

Table 1. Dependent variables and scale design

Social Response	Category	Dependent Variables Measured
Psychological/ Emotional Status	Frame of Mind	Anxiety(4 questions), Response Attitude(2 questions) , Perceive Ease of Use (4 questions)
	Involvement	Perceived Enjoyment(5 questions)
	Coenesthesia	Perceived Sociability(4 questions)
Attitude Towards the Robot	Responsive Feature	Social Influence(3 questions), Trust(3 questions), Social Presence(5 questions), Perceived Adaptability (3 questions) ,Perceived Usefullness(3 questions)

2. Experiment Subjects

A total of 100 subjects were recruited in this study, covering the afore-mentioned 4 age groups. Every participant would receive a $50 bonus card for remuneration upon their completion of the experiment tasks.

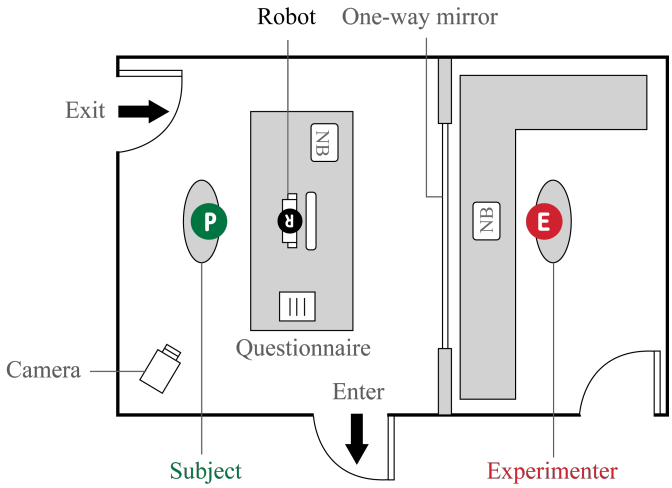

Figure 4. Layout of the laboratory

3. Research instruments

Layout of the laboratory was as shown in Figure 4. The research instruments used were as follows:

(1) Robot Alpha 1S
Alpha 1S, as shown in Figure 5, is a program-controlled robot developed by UBTech and capable of taking movement and speech commands from a mobile phone. It was used in this study for its operation flexibility and with Wizard of Oz method for delivering a more realistic interactive experience to the subjects.
(2) Laptop computers
Two computers, installed with Skype and networked, were placed in the laboratory and the observation room for the experimenter's convenient remote monitoring of the subjects' response.
(3) ASUS tablet PC
A tablet PC, installed with controlling APP for the Alpha 1S, was used for the experimenter's convenient manipulating of the robot's movement and speech.
(4) Camcorder
A camcorder, placed at a corner of the laboratory, was used to record the experiment.
(5) Microphone
A microphone, placed behind the robot, was used to pick up the subject's speeches so that the experimenter can hear the subject's response more clearly.

4. Experiment Design and Workflow

The experiment cost 10 to 15 minutes. Its workflow included: (1) Explanations of the experiment workflow and main points; (2) The robot's self-introduction; (3) Health consultation questions; (4) Limbs coordination exercises; (5) Scale completion. Once the experiment began, the experimenter would explain to the subject how to interact with the robot and would outline the tasks to the subject, then the experimenter would return to the observation room, where he would use a tablet PC to control the robot. The robot would first introduce itself to the subject and guide the subject to the task performance stage. A total of 2 tasks would be performed, the first task would be 5 "health consultation questions", as shown in Table 2; the second task would be 4 questions on "limbs coordination exercises", as shown in Table 3. Upon completion of all tasks, the subject would be asked to fill out a self-subjective scale.

Figure 5. Laboratory

Figure 6. Observation Room

Table 2. Health consultation questions

The health consultation questions were in the following order	
1	What time do you usually go to bed?
2	Do you have the habit to do exercises? What exercise(s) do you do?
3	Do you have the habit to eat fruit every day? What fruit(s) do you eat?
4	What habit(s) do you have that you think would be harmful to your health?
5	What habit(s) do you have that you think would be beneficial to your health?

Table 3. Limbs coordination exercises

The limbs coordination exercises were in the following order	
1	Clap hands for three times
2	Cross hands
3	Hand-eye coordination
4	Shoulder-arm coordination

Data Analysis

Experiment data of the 100 subjects were collected and subjected to factor analysis and confidence analysis for determining the validity and confidence of the questions in the questionnaire's aspects; the significance of every individual aspect to the factors was tested by one-way ANOVA. Finally, significant difference between age groups in terms of the factors was tested by Scheffe's post hoc procedure.

1. Sample structure

A total of 100 subjects, 38 males, 62 females, were recruited in the study. Age distribution of the subjects was as shown in Table 4.

Table 4. Age distribution of the subjects

Age Group	Age	Subjects
Youth	18 - 27	28
Mature	28 - 38	23
Middle-aged	39 - 49	24
Senior	≥50	25

2. Test of the questionnaire's validity

First, the 10 factors of the scale were subjected to Kaiser-Meyer-Olkin(KMO) test and Bartlett's sphericity test to determine their suitability for factor analysis. These factors had to have a KMO-measure greater than 0.7 and a p-value less than 0.05 in Bartlett's sphericity test. 8 factors, as shown in Table 5, remained after unsuitable items had been culled out.

Table 5. KMO and p-value of the questionnaire's factors

Factor	KMO-measure	p-value
Anxiety	0.704	0.000
Perceived Enjoyment	0.817	0.000
Perceived Sociability	0.777	0.000
Perceived Adaptability	0.721	0.000
Perceived Usefullness	0.697	0.000
Social Influence	0.706	0.000
Social Presence And Reality	0.812	0.000
Trust	0.691	0.000

3. Test of the questionnaire's confidence

The remaining 8 factors of the questionnaire were assessed by their Cronbach's alpha to determine the confidence of the questionnaire. According to DeVellis & Dancer(1991), a Cronbach's α in the range of 0.65 ~ 0.70 is acceptable; a Cronbach's α in the range of 0.70 ~ 0.80 suggests high confidence; a Cronbach's α greater than 0.80 indicates optimal confidence. Some questions would be culled out in order to increase a factor's Cronbach's α. The Cronbach's α values after the culling out were as shown in Table 6.

Table 6. Cronbach's alpha of the factors

Factor	α
Anxiety	0.791
Perceived Enjoyment	0.869
Perceived Sociability	0.796
Perceived Adaptability	0.830
Perceived Usefullness	0.854
Social Influence	0.813
Social Presence And Reality	0.884
Trust	0.748

4. Analysis of the subjects' interactive behaviors and emotion by age groups

In order to determine whether an independent variable was significant to individual dependent variables, one-way ANOVA was carried out. First, the mean p-values of the independent variables to the factors were listed in the following Table 7 to determine whether there was any significant difference between the factors.

As the experiment's age groups had different number of subjects(28/23/24/25), Scheffe's post hoc procedure was used to test the difference. As can be seen in Table7, significant difference($p < 0.05$) was identified in the factors of *Perceived Enjoyment*, *Perceived Adaptability*, *Social Presence and Reality*.

Table 7. Factor analysis of the age groups

Factor	Youth	Mature	Middle-aged	Senior	P -value
Anxiety	2.87	2.90	2.53	2.73	0.474
Perceived Enjoyment	3.44	3.34	3.78	3.87	0.034*
Perceived Sociability	3.82	3.90	4.10	4.25	0.105
Perceived Adaptability	3.54	3.48	3.76	4.04	0.016*
Perceived Usefullness	3.44	3.45	3.76	3.86	0.104
Social Influence	3.64	3.57	3.89	3.87	0.355
Social Presence and Reality	2.97	2.84	3.46	3.69	0.001*
Trust	3.42	3.29	3.68	3.79	0.061

Conclusion

Statistical analysis results of HRI revealed that subjects in Senior group had higher *Perceived Enjoyment* and *Perceived Adaptability* ratings than subjects in Mature group. It is generally believed that senior people may repulse or misfit robots. In our interactive environment with the health coach robot, however, subjects in the Senior group yielded the highest rating in terms of the enjoyment arising from HRI and the response to adaptability to change.

On the other hand, statistics showed subjects in the Senior group had relatively higher perceived *Social Presence and Reality* than subjects in the Youth group and the Mature group, suggesting that compared to people in their young/prime days, people in their old age may tend to treat the robot as a true human being or a living thing.

It was originally hoped that the experiment design and interview would help to find out the subjects' opinions after their interaction with the robot. However, the subjects proposed basically indiscrepant suggestions regardless of their age groups. Generally speaking, most people included "excessive joint noise", "less prompt reply speed", and "less clear-cut demonstration of limbs coordination exercises" as the robot's shortcomings and mentioned "an acceptable partner", "a fashionable pet to have", and "the ability to give health advices" as the robot's merits. However, the experiment at this stage could not give any advices on the interaction with the robot for subjects of any specific age groups.

The interview revealed that subjects in the Youth group and the Mature group were curious about the robot's internal program and actual functions; subjects in the Middle-aged group and the Senior group on the other hand were more intrigued by the robot's appearance. It is suggested that physiognomical questions such as appearance, functions, voice, and impression should be included as topics of the interview in order to yield more discriminating opinions.

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