Investigation of Differences on Impressions of and Behaviors toward Real and Virtual Robots between Elder People and University Students

Tatsuya Nomura, *Member, IEEE* and Miyuki Sasa

***Abstract*— To investigate differences on impressions of and behaviors toward anthropomorphized artifacts between different generations, a psychological experiment was conducted with between-subjects design of the elderly vs. university students and a small-sized real humanoid robot vs. a virtual CG robot on a computer display. The results showed that 1) more elderly subjects complied with the real robot than the student subjects, 2) the elderly subjects felt more positive impressions of both the robots than the student subjects, 3) the student subjects felt less attachment to the virtual robot than the real robot, and 4) the student subjects felt less attachment to the virtual robot in comparison with the elderly subjects. Then, the paper discusses implications on assistive robots for the elderly in domestic fields.**

I. Introduction

It is estimated that there are several differences between elder and younger people on cognitive and behavioral characteristics toward anthropomorphized artifacts such as robots and animation characters on screens. In fact, cognitive engineering focuses on age effects to explore human-interface designs having high usability for the elderly [1]. On the other hand, robots are expected as one of assistive technologies in home for the elderly, in particular, in industrialized countries including Japan, due to the decrease in rates of childbirth and the increase in the elderly population [2]. On considering the designs of these robots in domestic fields, it is necessary to clarify differences between elder and younger people on cognitive and behavioral characteristics toward robots.

However, there are only a few studies on direct comparison between elder and younger people focusing on robots. In an international study in several countries (Japan, United Kingdom, Sweden, Italy, and Korea), Shibata, Wada, and Tanie [3] developed and reported on participants' subjective evaluations of a seal-type robot called "Palo". Their results suggested that younger people had more favorable impressions of the robot than older people. Dautenhahn, et al., [4] reported results of a human-robot interaction experiment conducted in the United Kingdom which suggested that in the future, younger people compared to older people would like to have a home robot companion. Scopelliti, et al., [2] conducted a social research study in Rome and reported that younger people had more familiarity with robots than older adults. Moreover, Nomura, et al., [5] found that middle-aged Japanese visitors had more positive evaluations of a robot exhibit than younger visitors.

The above existing studies measured participants' impressions and attitudes toward robots after interaction with some specific types of robots or instruction about scenes of using robots. However, they lack a comparison on concrete behaviors in interaction with robots between elder and younger subjects. Moreover, it was found that the difference on robot appearance (really existing robots or virtual CG animation robots) affects human cognition toward robots [6]. When considering the introduction of robots from the perspective of cost and benefit, we should take into account the problem on which we should select virtual robots that can be implemented on the existing computers, or real robots that need other physical structures.

Thus, the following research questions should be investigated:

-- ***RQ1***: Are there differences between elder and younger people on concrete behaviors and impressions toward robots in interaction with them?

-- ***RQ2***: Are there differences between really existing robots and virtual CG animation robots on the above psychological reactions? If so, are there differences about them between elder and younger people?

To investigate the above research questions, a psychological experiment was conducted. The paper reports the results of the experiment and discusses their implications on assistive robots for the elderly in domestic fields.

II. Method

A. Subjects

The experiment was conducted from October to December, 2008. A total of thirty seven persons participated to the experiment.

The number of the elder subjects was twenty (male: 10, female: 10, age: min 59, max 79, mean 68.7). They were inhabitants at a local city in the western area of Japan, and recruited through a survey company. Five thousands yen was paid for each subject.

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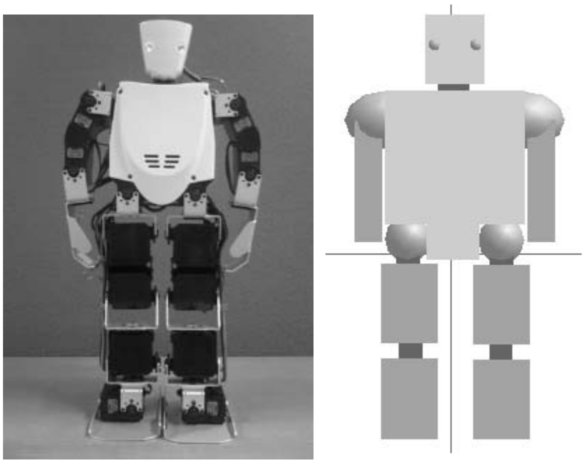
Tatsuya Nomura is with Department of Media Informatics, Ryukoku University, Otsu, Shiga 520-2194, Japan, and ATR Intelligent Robotics and Communication Laboratories, Japan. (phone: +81-77-544-7136; fax: +81-77-544-7150; e-mail: nomura@rins.ryukoku.ac.jp).

Miyuki Sasa is with Department of Media Informatics, Ryukoku University, Otsu, Shiga 520-2194, Japan



Real Robot: Robovie-X Virtual CG Robot

Fig. 1. Robots used in the experiment

The number of the younger subjects was seventeen (male: 7, female: 10, age: min 19, max 22, mean 20.6). They were university students in the western area of Japan, and recruited with one thousand yen.

B. Robots Used in the Experiment

In the experiment, a small-sized humanoid robot and CG animation robot similar to this humanoid robot were used.

The humanoid robot was "Robovie-X" shown in the left figure of Fig. 1, which has been developed by Vstone Corporation. This robot stands 34.3 cm tall and weighs about 1.3 kg. The robot has a total of 17 DOFs at its feet, arms, and head. This large number of DOF allows it to execute various gestures such as walking, bowing, and a handstand. Moreover, this robot has a function of utterance based on audio data recorded in advance such as Windows WAV files, which is limited to 300 KB.

The virtual CG robot shown in the right figure of Fig. 1 was created based on 3D software "Hexa," produced by Shusaku Co., Ltd., and implemented on a laptop computer, Lenovo ThinkPad G41 (CPU: 2.66GHz, 15 inch TFT color liquid display).

C. Task for Subjects, Voice and Behaviors of the Robots

The task to be requested for subjects in the experiment was manipulation of physical objects on a desk. This task is similar with the one conducted in the experiment on influences of robot physical appearances into human perception [6]. In the experiment, it was instructed by the robots with voice.

Voice data consisting of Japanese sentences was synthesized from text data by using "Easy Speech" (free software), Microsoft SPAI 4.0, and L & H TTS 3000. The quality of the voice was artificial and neutral independent on gender. Then, it was played by the robot and laptop computer, as instructions from the robots to subjects. The instructions were common in both the robots. They were presented as follows:

-- "Hello, I am Robovie-X. There are some writing utensils in front of you. Among them, please pick up a pen and eraser and put them into the red box at the right side, and then pick up a knife and adhesive and put them into the blue box at the left side."

During the above voice instructions, the robots bowed and raised their right arms at the stage of the introduction. Then, they inclined their bodies and hold out their hands toward the boxes when asking the subjects to sort out the writing utensils. In the case of Robovie-X, these behaviors were produced by the accessory software "RobovieMaker2" and installed into the robot in advance.

D. Procedures

The experiment adopted a 2 x 2 between-subjects design of the elderly vs. university students and real vs. virtual CG robot. Each session was conducted based on the following procedures.

-- **1**: Each subject was explained about the experiment and signed the consent form about dealing with data including video-recording. In this stage, the experimenters only indicated that the task in the experiment was interaction with a robot or computer, and they planed to video-record the scene in the experiment.

-- **2**: The subject was led to an experiment room, in which either real or virtual robot, writing utensils, and boxes were put on a desk, as shown in Fig. 2. The experimenters instructed him/her to sit on the chair in front of the desk and wait in the room for a while, and left the room.

-- **3**: Just after the subject was left alone in the room, the robot started the instruction for him/her to sort out the writing implements as mentioned in the previous section. It was remotely controlled by the experimenters out of the

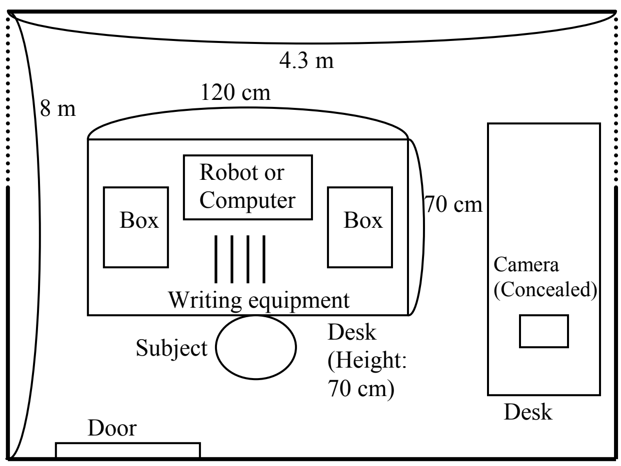


Fig. 2. Overview of the room where the experiment was executed (a view from above)

TABLE I
PAIRS OF ADJECTIVES FOR MEASURING SUBJECTS' IMPRESSIONS OF THE ROBOTS (ORDER APPEARING IN THE QUESTIONNAIRE)

Positive		Negative
Mild	---	Terrible
Fine	---	Ill
Familiar	---	Unfamiliar
Safe	---	Dangerous
Warm	---	Cold
Cheerful	---	Gloomy
Chatty	---	Formal
Comprehensible	---	Not comprehensible
Approachable	---	Unapproachable
Light	---	Dark
Considerate	---	Selfish
Human	---	Mechanical
Full	---	Empty
Funny	---	Boring
Pleasant	---	Unpleasant
Favorite	---	Disfavorite
Interesting	---	Tedious
Good	---	Bad
Complex	---	Simple
Fast	---	Slow
Rapid	---	Dull
Violent	---	Gentle
Aggressive	---	Negative
Bold	---	Timid
Showy	---	Plain
Cheerful	---	Gloomy
Sensitive	---	Insensitive
Clever	---	Foolish

room.

-- **4**: When the subject finished the instructed task or ninety seconds passed without performing the task, the experimenters entered the room again, and indicated that the session finished. Then, the experimenters conducted debriefing about the actual aim of the experiment and the fact that the session was video-recorded by a camera concealed from the subject.

-- **5**: Then, the experimenters interviewed with the subject about the robot and the future society related to robots. Finally, the subject responded a questionnaire for measuring his/her impression of the robot.

E. *Measures*

As mentioned in the previous section, the scenes of the experiment were recorded with a digital video camera to extract the subjects' concrete behaviors toward the robots.

The questionnaire for measuring the subjects' impressions of the robots consists of twenty eight pairs of adjectives shown in Table I. The subjects were asked to respond to each pair of adjectives to present degrees to which they felt the impression of the robots they experienced. These adjectives are the ones used for measurement of subjects' impression in an experiment of interaction with a humanoid robot [7]. Each questionnaire item had a score for rating with seven intervals (1-7). On the questionnaire, it was randomized at each item which side the positive or negative adjective appeared at.

TABLE II
NUMBERS OF SUBJECTS ASSIGNED TO THE CONDITIONS IN THE EXPERIMENT

	Students			Elderly		
	Male	Female	Total	Male	Female	Total
Real Robot	3	5	8	5	5	10
Virtual Robot	4	5	9	5	5	10

TABLE III
RATES OF SUBJECTS WHO PERFORMED THE TASK AND RESULT OF χ^2-TEST

Students		Elderly	
Real	Virtual	Real	Virtual
7/8	7/9	9/10	9/10

($\chi^2(3) = .802$, *n.s.*)

TABLE IV
RATES OF SUBJECTS WHO PERFORMED UTTERANCE OR GREETING BEHAVIORS TOWARD THE ROBOTS AND RESULT OF χ^2-TEST

Students		Elderly	
Real	Virtual	Real	Virtual
3/8	1/9	7/10	5/10

($\chi^2(3) = 6.997$, $p < .1$)

III. RESULTS

Table II shows the numbers of subjects assigned to the conditions in the experiment. To investigate the effects of robot type and age into the subjects' concrete behaviors toward and impressions of the robots, the following analyses were performed.

A. *Behaviors toward the Robots*

Based on the video data, the following behavioral indices were extracted:

-- BI1: Whether each subject performed the task of sorting out the writing utensils instructed by the robot he/she faced,

-- BI2: Whether each subject uttered or greeted toward the robot during or after the instruction from it.

Then, χ^2-tests were performed for the cross tables on these indices to compare between the conditions of robot and age.

Table III shows the rates of subjects who performed the task. χ^2-test revealed no statistically significant difference on the rates between the conditions of robot and age.

Table IV shows the rates of subjects who uttered or greeted toward the robot. χ^2-test showed a statistically significant trend. The residual analysis ($\alpha = .05$) revealed that the rate in the real robot – elderly condition was higher and that in the virtual robot – students condition was lower than the average level at a statistically significant level.

B. *Impressions of the Robots*

For each item of adjectives pair, the score of the seven-graded answer was coded from 1 to 7 so that higher score corresponded to the positive adjective of the pair. Then, exploratory factor analysis with maximum-likelihood method and promax rotation was performed to classify these items and extract subscales for measuring the subjects' impressions of the robots. This factor analysis was

TABLE V

RESULT OF EXPLORATORY FACTOR ANALYSIS FOR IMPRESSIVE ADJECTIVE ITEMS (MAXIMUM-LIKLIHOOD METHOD AND PROMAX ROTATION) AND RESULTS OF ITEM ANALYSIS

Adjective (positive)	Factor Loading I	II	III	IV	h^2	Note
Good	**1.141**	-.080	-.215	.002	.966	
Interesting	**1.032**	-.298	-.166	.110	.634	
Funny	**.834**	.104	-.46	-.014	.769	
Light	**.708**	.117	.052	-.005	.676	
Pleasant	**.634**	-.096	.235	.045	.537	
Cheerful	**.623**	.088	.260	-.049	.757	
Clever	**.589**	.164	.010	.334	.612	
Favorite	**.531**	.315	-.039	-.196	.596	
Showy	**.452**	.366	.014	-.207	.602	
Approachable	**.450**	.430	-.072	.062	.574	
Aggressive	**.440**	.355	-.025	-.065	.501	
Complex	.187	-.038	.075	.144	.064	
Familiar	-.125	**1.172**	-.203	-.160	.984	
Fine	-.047	**.822**	-.083	.160	.615	
Comprehensible	.092	**.644**	-.028	.098	.498	
Mild	-.006	**.498**	.278	.035	.485	
Safe	-.027	***.483***	-.078	.122	.210	Removed by item analysis
Human	-.175	**.467**	.446	.092	.507	
Warm	-.173	-.124	**1.001**	-.141	.750	
Pretty	-.067	-.094	**.717**	.062	.403	
Chatty	.412	-.161	**.552**	-.136	.612	
Sensitive	.440	-.137	***.485***	.119	.550	Removed by item analysis
Rapid	.265	.219	**.385**	-.178	.590	
Fast	.082	.234	.289	-.270	.342	
Full	.243	.262	.273	.143	.470	
Considerate	-.049	.335	.202	***.864***	1.000	Removed by item analysis
Bold	-.015	.124	.079	***-.689***	.490	Removed by item analysis
Violent	.108	.096	-.184	***.504***	.285	Removed by item analysis

Subscale	#/. items	Chronbach'α
I:Activeness	11	.934
II: Familiarity	5	.852
III: Attachment	4	.851
Correlations	I:Activeness	II: Familiarity
II: Familiarity	.647**	---
III: Attachment	.614**	.585**

(** $p < .01$)

performed assuming four-factor structure since the existing study using these items found the four factors [7]. Moreover, item analysis using Chronbach's α-coefficients and I-T correlations was performed for each factor to select items in the corresponding subscale. Table V shows the results of these analyses.

The first factor consisted of eleven items and the item analysis found no item to be removed. The contents of the corresponding items suggested the impression related to the robots' positive activities. Thus, the corresponding subscale consisting of eleven items was interpreted as "activeness". The second factor consisted of six items and item analysis found one item to be removed. Based on the contents of the corresponding five items, this subscale was interpreted as "familiarity". The third factor consisted of five items and item analysis found one item to be removed. The contents of these four items suggested the impression related to the robots' cuteness or attachment to the robots. Thus, the corresponding subscale was interpreted as "attachment". The fourth factor was removed from the analysis because of its low correlations to the other three factors (< .26, *n.s.*) and low internal consistency (Chronbach's α = .637).

The score of each impression subscale was calculated as the sum of the scores of the corresponding items. Thus, the maximum and minimum scores are 77 and 11 for "activeness" subscale, 35 and 5 for "familiarity" subscale, and 28 and 4 for "attachment" subscale, respectively. Then, to compare the subjects' impressions of the robots between the conditions, two-way ANOVAs with robot X age were performed for the scores of the three subscales. Fig. 3 shows the means and standard deviations of these subscale scores and results of the ANOVAs.

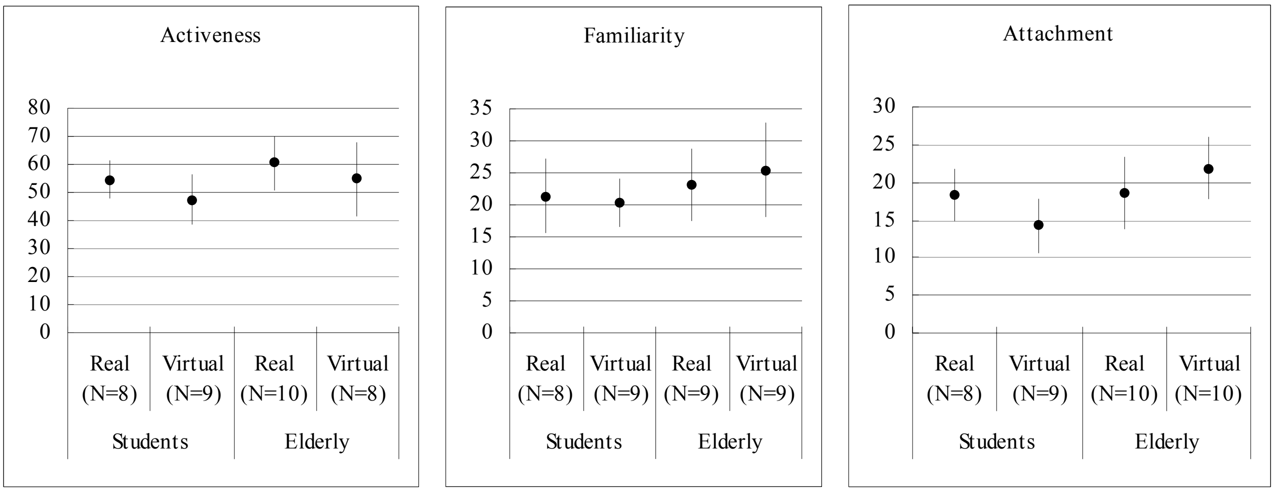
As a result, the main effects of age and robot were at statistically significant trend levels for the scores of "activeness". The main effect of age was also at a statistically significant trend level for the scores of "familiarity". For the scores of "attachment", the main effect of age and interaction effect were statistically significant. Post-hoc analysis with Bonferroni's method ($\alpha = .05$) found that the scores in the condition of the virtual robot and students were lower than those in the condition of the virtual robot and the elderly and those in the condition of the real robot and students at statistically significant levels.

IV. DISCUSSION

A. Findings

The results in section 3 provide with some answers for the research questions mentioned in section 1.

On RQ1, differences between elder and younger people on concrete behaviors and impressions toward robots in interaction with them, more elderly subjects complied with



	F-values		
	Activeness	Familiarity	Attachment
Age	4.041†	2.928†	9.025**
Robot	3.744†	.127	.074
Interaction	.052	.784	7.519**

($^{\dagger}p < .1$, $^{**}p < .01$)

Fig. 3. Means and standard deviations of impression scores, and results of ANOVAs with age X robot

the real robot than the student subjects, although most of both subjects followed the instructions from the robots. Moreover, the elderly subjects felt more positive impressions of the robots than the student subjects.

On RQ2, differences between really existing robots and virtual CG animation robots on the reactions and relationships to age, the student subjects felt less attachment to the virtual robot than the real robot. Moreover, the student subjects felt less attachment to the virtual robot in comparison with the elderly subjects.

B. Implications on Domestic Robots

The above results lead us to some implications on domestic robots. First, elder people may more positively accept robots as social entities than younger people.

Second, elder people may be less sensitive for the differences between robots with real bodies and virtual robots on computer screens than younger people. In fact, the experimental results showed no statistically significant differences between the real and virtual robots on the elder subjects' impressions related to familiarity and attachment. Of course, the second implication may be dependent on tasks that robots and elder people perform together.

Important is that the above trend in the Japanese subjects of the experiment is opposite to those in Europe suggested by Scopelliti, et al., [2] and Dautenhahn, et al., [4]. This fact suggests cultural differences on age effect into the acceptability of domestic robots.

C. Limitations

We only tested with a particular type of robots with a limited interaction with subjects from specific groups. In particular, the interaction between the subjects and robots in the experiment was one way where the robots only performed a script and had no reaction for the subjects' behaviors. Thus, the generality of our findings is limited. We believe that they are applicable to interactions with a robot of similar size and appearance, and interactions of similar complexity. Nevertheless, our current research has some problems.

First, we adopted single task, size, and appearance except for the difference between real and virtual ones. Goetz et al. proposed a "matching hypothesis" to explore relationships between robot appearances and tasks, and found that friendlier tasks matched friendlier appearances [8]. Kidd and Breazeal found that real robots were more suitable than virtual ones for tasks such as pointing at objects in real surroundings [6]. Thus, we should consider interaction effects of task, appearance including size, and age.

Second, we did not consider subjects' personal traits such as gender, educational backgrounds, and psychological constructs related to robots. Mutlu et al. found effects of gender and task structures on human perceptions of a humanoid robot (ASIMO) [9]. Nomura et al. suggested relationships between negative attitudes, emotions, and communication avoidance behaviors toward robots, and gender effect on them [10]. Thus, we should consider both age and other personal traits.

Finally, the total number of subjects in the experiment was not sufficient. It is critical from the perspective of factor analysis performed in section 3. In fact, the factor structure differed from that extracted in the existing study [7]. Moreover, our control of the experimental conditions was also insufficient, for example, the usage of different experiment rooms (with and without windows) and consideration of elder subjects' cognitive (auditory and visual) characteristics.

The aforementioned problems must be tackled in future experiments by extending the experimental design, for example, by sampling from more groups and using several types of robots, tasks, and demographic variables.

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