Human Evaluation of Affective Body Motions Expressed by a Small-Sized Humanoid Robot: Comparison between Elder People and University Students

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***Abstract*— Body motion expression is one of the useful methods that robots present their emotional states toward users. Since emotions themselves have cultural dependency, however, it is estimated that effects of affective body motions depend on users' demographic factors such as gender and age. In order to clarify this dependence, a psychological experiment was conducted to investigate age differences on evaluation of affective body motions which were implemented into a small-sized humanoid robot. The results showed differences between younger and elder people on identification of emotions, body parts paid attention to, and impression of motion speed and magnitude for the affective body motions of the robot. The paper also discusses about the implications.**

I. Introduction

BODY motion expression is one of channels for communication between humans. It has a possibility of contribution to human-robot interaction, in particular, affective information from robots to humans. In fact, some researchers have been proposing and analyzing mechanisms of body motion expression in robots (e.g., [1][2][3]).

However, some psychologists and sociologists argue that interpretation of emotional expressions are dependent on societies and cultures [4][5]. It leads us to an assumption that effects of affective body motions expressed by robots depend on users' demographic factors such as gender and age. In particular, age dependence should be investigated in the current situation that human-robot interaction is expected as one of assistive technologies in home for the elderly in industrialized countries including Japan, due to the decrease in rates of childbirth and the increase in the elderly population.

Thus, the paper focuses on the following research question "**Are there differences on evaluation of affective body motions expressed by robots between younger and elder people?**" For this aim, a psychological experiment was conducted. In this experiment, some affective body motions were implemented into a small-sized humanoid robot. The paper reports results of the experiment and discuss about their implications.

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II. Method

A. Subjects

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

The number of the elder subjects was fifteen (male: 9, female: 6, age: min 64, max 79, mean 69.1). 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.

The number of the younger subjects was seventeen (male: 8, female: 9, age: min 18, max 23, mean 20.8). They were university students in the western area of Japan, and recruited with one thousand yen.

B. The Robot Used in the Experiment

In the experiment, a small-sized humanoid robot shown in Fig. 1 was used. This robots "Robovie-X," which has been developed by Vstone Corporation, 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.

Although this robot has a function of utterance based on audio data recorded in advance such as Windows WAV files, this function was not used in the experiment since body motions were the research focus.

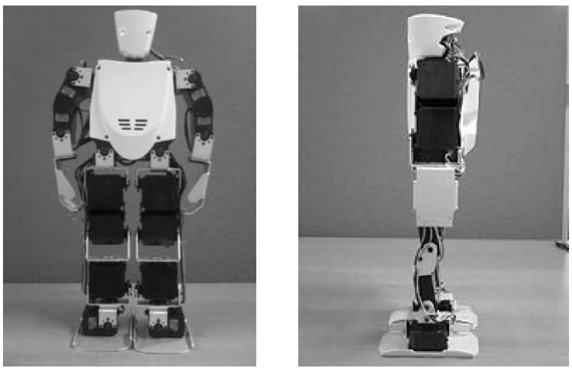


Fig. 1. Robovie-X (left figure: front view, right figure: side view)

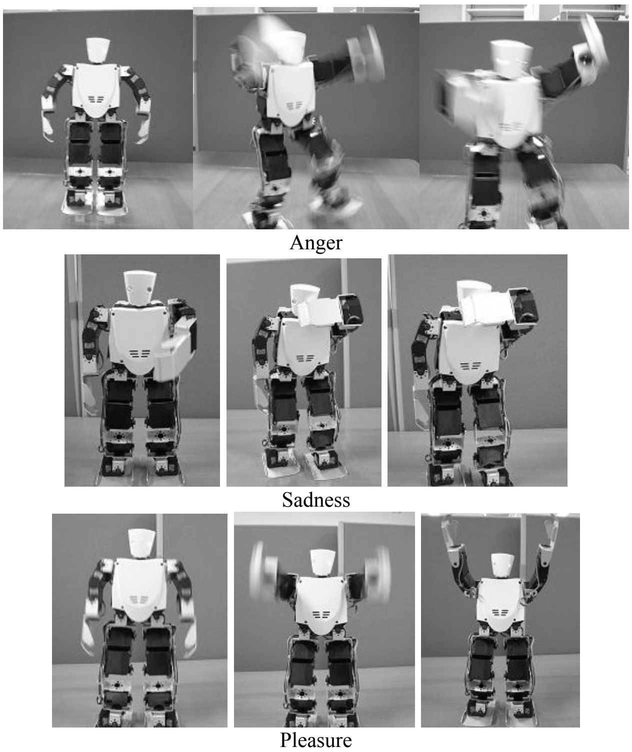


Fig. 2. Affective Body Motions by Robovie-X

C. Affective Body Motions of the Robot

The research focused on three basic emotions, anger, sadness, and pleasure to simplify the experimental design. Based on the existing studies on affective body motions [1][2][3] and a literature on modern dances [6], motions corresponding to these emotions were defined as follows:

-- **Anger**: After the robot wave its arms fast and little by little, it marches forward while violently shaking the arms up and down by turns and stepping (like stamping its foot). The speed of the whole motion is high.

-- **Sadness**: The robot bends down a little, and then hides its face with one hand while slowly waving the head on both sides (like wiping its eyes). The speed of the whole motion is low.

-- **Pleasure**: With its open arms, the robot repeats the motion of shaking both the arms up and down (like giving cheers). The speed of the whole motion is high.

The above motions were programmed into Robovie-X by using the accessory software "RobovieMaker2." Fig.2 shows some parts of these affective body motions.

D. Procedures

Each session in the experiment was conducted based on the following procedures.

-- **1**: Each subject was explained about the experiment and signed a consent form in a room. In this stage, the experimenters only indicated that the task in the experiment was interaction with a robot or computer.

-- **2**: The subject was led to an experiment room, in which the robot was put on a desk, as shown in Fig. 3. After sitting in front of the robot, the subject was more concretely explained about the experiment by the experimenter.

-- **3**: First, the subject answered a questionnaire consisting of demographics including gender and age. Then, three types of affective body motion were expressed by Robovie-X in randomized order. Just after each expression, the subject answered a questionnaire to evaluate each body motion.

-- **4**: Finally, the experimenter conducted debriefing about the actual aim of the experiment and interview on impressions of robots.

E. Measures

The measurement in the experiment was based on a self-reported method. The questionnaire for measuring the subjects' evaluation of affective body motions was designed based on the existing study [1]. For each affective body motion expressed by the robot, the questionnaire consisted of three parts; a group of items to measure which emotion and to which degree the subjects felt the expressed motion corresponded to, those to measure which part of the robot motion they paid their attentions to, and those to measure their impression of the magnitude and speed of the motion.

The first part of the questionnaire consisted of seven items corresponding to some basic emotions shown in Table I. The subjects were asked to respond to each item to present degrees to which they felt the expressed motion looked like the specified emotion. Each item had a three-graded answer as shown in Table I. Considering proximity between some emotions [7], the research adopted the way that subjects evaluated plural emotions for one affective body motion.

The second part of the questionnaire consisted of nine

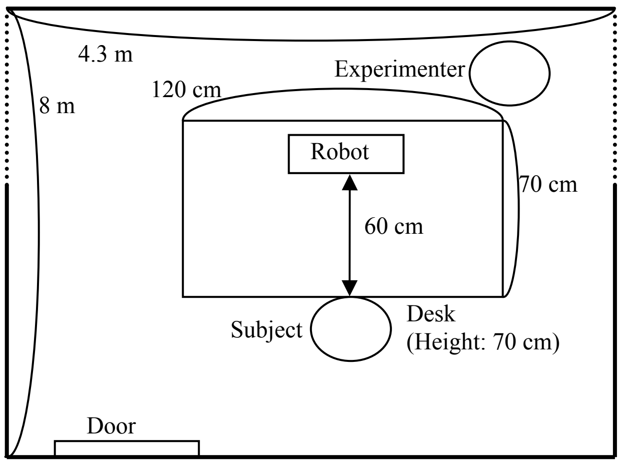


Fig. 3. Overview of the room where the experiment was executed (a view from above)

TABLE I
ITEM SENTENCES TO EVALUATE AFFECTIVE BODY MOTIONS EXPRESSED BY THE ROBOT

Does the robot look like fearful?
Does the robot look like pleasant?
Does the robot look like sad?
Does the robot look like hateful?
Does the robot look like surprised?
Does the robot look like angry?
Does the robot look as if it expresses other emotions?

(Grade of answer: 1. I strongly think so, 2. I think so, 3. I do not think so)

items corresponding to the following body and motion parts: head, arms, hands, upper body, legs, feet, speed of motion, magnitude of motion, and others. The subjects were asked to respond to each item to present degrees to which they paid their attentions to the corresponding body or motion part. Each item had a three-graded answer: 1. I paid much attention, 2. I paid a little attention, 3. I paid no attention.

The third part of the questionnaire consisted of two items. One asked the subjects to answer degrees to which they felt the speed of the expressed motion was fast or slow. This item had a five-graded answer (1. I felt it very fast, 2. I felt it fast, 3. undecided, 4. I felt it slow, 5. I felt it very slow). Another item asked the subjects to answer degrees to which they felt the magnitude of the expressed motion was large or small. This item also had a five-graded answer (1. I felt it very large, 2. I felt it large, 3. undecided, 4. I felt it small, 5. I felt it very small).

III. RESULTS

A. Identification of Affective Body Motions

First, it was investigated whether there were differences on emotion identification for the body motions by the robot between the elder and student subjects. To simplify the analysis, answers "1. I strongly think so" and "2. I think so" were coded as 1: "identification as the specified emotion," and others were coded as 0: "no identification as the specified emotion." Table II shows the numbers of subjects who identified the presented affective motion as the specified emotions and results of Fisher's exact tests for cross tables based on distinction between students and the elderly.

For the body motion of anger, the rates of those who identified it as anger and hate in the student subject group were larger than those in the elderly subject group at statistically significant levels. For the body motion of sadness, the rates of those who identified it as sadness and hate in the student subject group were larger than those in the elderly subject group at statistically significant levels. For the body motion of pleasure, there was no statistically significant difference on identification of the specified emotions between these groups.

TABLE II
NUMBERS OF SUBJECTS WHO IDENTIFIED ROBOT AFFECTIVE BODY MOTION S AS THE SPECIFIED EMOTIONS AND RESULTS OF FISHER'S EXACT TESETS

For Anger Motion	Students ($N = 17$)	Elderly ($N = 15$)	Fishers' test p
Fear	5	5	1.000
Pleasure	7	11	.087
Sadness	2	3	.645
Hate	15	3	.000
Surprise	5	9	.153
Anger	17	4	.000
Others	1	3	.319

For Sadness Motion	Students ($N = 17$)	Elderly ($N = 15$)	Fishers' test p
Fear	8	2	.060
Pleasure	0	2	.212
Sadness	17	11	.038
Hate	11	3	.016
Surprise	0	0	1.000
Anger	0	0	1.000
Others	4	2	.659

For Pleasure Motion	Students ($N = 17$)	Elderly ($N = 15$)	Fishers' test p
Fear	0	1	.469
Pleasure	16	12	.319
Sadness	1	2	.589
Hate	1	1	1.000
Surprise	9	3	.076
Anger	2	1	1.000
Others	4	2	.659

B. Attention to Body and Motion Parts

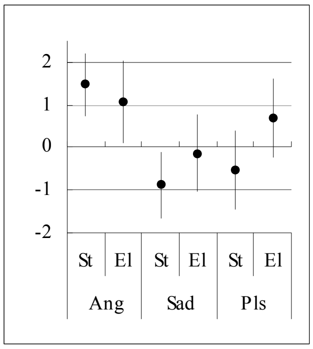
Second, it was investigated whether there were differences between the elder and student subjects on body and motion parts they paid their attentions to. To simplify the analysis, answers "1. I paid much attention" and "2. I paid attention a little" were coded as 1: "attention to the specified part," and others were coded as 0: "no attention to the specified part." Table III shows the numbers of subjects who paid their attentions to the specified part of body and motion for each affective motion and results of Fisher's exact tests for cross tables based on distinction between students and the elderly.

For the body motion of anger, the rate of those who paid their attentions to the upper body of the robot in the student subject group was smaller than that in the elderly subject group at a statistically significant level. For the body motion of sadness, the rates of those who paid their attentions to the legs, feet, magnitude of motion, and other parts of the robot in the student subject group were smaller than those in the elderly subject group at statistically significant levels. For the body motion of pleasure, there was no statistically significant difference on attentions to the specified parts of body and motion between these groups.

TABLE III
NUMBERS OF SUBJECTS WHO PAID ATTENTIONS TO THE SPECIFIED PART OF BODY AND MOTION FOR EACH AFFECTIVE BODY MOTION OF THE ROBOT AND RESULTS OF FISHER'S EXACT TESETS

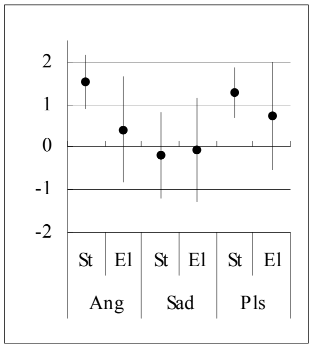
	Students (N = 17)	Elderly (N = 15)	Fishers' test p
For Anger Motion			
Head	5	9	.153
Arms	15	15	.486
Hands	17	15	1.000
Upper body	9	14	.018
Legs	17	15	1.000
Feet	17	15	1.000
Speed of motion	17	15	1.000
Magnitude of motion	17	15	1.000
Others	3	5	.423
For Sadness Motion			
Head	16	14	1.000
Arms	17	15	1.000
Hands	17	14	.469
Upper body	14	14	.603
Legs	6	12	.016
Feet	3	10	.010
Speed of motion	10	13	.122
Magnitude of motion	9	14	.018
Others	0	5	.015
For Pleasure Motion			
Head	7	11	.087
Arms	17	15	1.000
Hands	14	15	.229
Upper body	15	15	.486
Legs	16	12	.319
Feet	11	10	1.000
Speed of motion	15	14	1.000
Magnitude of motion	17	14	.469
Others	1	2	.589

Impression of Motion Speed



Age: $F(1,30) = .192$
Motion: $F(2,60) = 33.801$***
Interaction: $F(2,60) = 3.719$*

Impression of Motion Magnitude



Age: $F(1,30) = 24.099$*
Motion: $F(2,60) = 16.378$***
Interaction: $F(2,60) = 3.825$*
(*$p < .05$, **$p < .01$, ***$p < .001$)

Fig. 4. Means and Standard Deviations of Speed and Magnitude Impression Scores and Results of ANOVAs
(St: student subjects, El: elderly subjects, Ang: anger motion, Sad: sad motion , Pls: pleasure motion)

C. Impression of Motion Speed and Magnitude

Third, it was investigated whether there were differences on impression of the magnitude and speed of the motion between the elder and student subjects. For this aim, the scores of the speed impression item were coded within the range from -2 to 2 (-2: "I felt it very slow," -1: "I felt it slow," 0: "undecided," 1: "I felt it fast," 2: "I felt it very fast"). Moreover, the scores of the magnitude impression item were also coded within the range from -2 to 2 (-2: "I felt it very small," -1: "I felt it small," 0: "undecided," 1: "I felt it large," 2: "I felt it very large"). Then, two-way ANOVAs with age x motion were performed for these scores. Fig. 4 shows the means and standard deviations of the scores and results of the ANOVAs.

The results found a statistically significant main effect of age in the magnitude impression scores. Moreover, they found statistically significant main effects of affective body motions in both speed and magnitude impression scores. Furthermore, there were statistically significant interaction effects of age and motion in both the speed and magnitude impression scores. Post-hoc tests with Boferroni's method found that: for the sadness motion the speed impression scores in the student subjects were lower than those in the elderly subjects, in the student subjects the speed impression scores for the sadness motion was lower than those for the other motions, and in the elderly subjects the scores for the sadness motion was lower than those for the angry motion. Moreover, they found that: for the angry motion the magnitude impression scores in the student subjects were higher than those in the elderly subjects, and in the student subjects the magnitude impression scores for the sadness motion was lower than those for the other motions. There was no statistically significant difference in the other comparisons.

TABLE IV
CORRELATION COEFFICIENTS BETWEEN ITEMS OF EMOTION JUDGMENT, ATTENTION TO BODY PARTS, AND IMPRESSION OF MOTIONS

For Anger Motion		
	Judgment as hate	Judgment as anger
Attention to upper body	-.131	-.306†
Magnitude impression	.405*	.302†
For Sadness Motion		
	Judgment as sadness	Judgment as hate
Attention to legs	-.143	.016
Attention to feet	-.265	-.088
Attention to motion magnitude	-.236	0.131
Attention to other parts	-.358*	-.206
Speed impression	-.328†	-.319†

(†$p < .1$, *$p < .05$)

D. Correlations between Emotion Identification, Attention to Body Parts, and Impression of Motions

Finally, correlation analysis was performed to investigate relationships between the subject's emotion identification for, their attentions to body and motion pars for, and their impressions of the affective body motions by the robot. These correlation coefficients were calculated between the items showing differences between the student and elder subjects. Table IV shows the correlation coefficients. The values between the items of emotion identification and attention to body and motion parts mean ψ-coefficients, and those between the items of emotion identification and motion impression means point biserial correlation coefficients, respectively.

For the anger motion, the identification as hate and anger were positively correlated with the magnitude impression at moderate levels. The identification as anger was also negatively correlated with the attention to upper body at a moderate level. For the sadness motion, the identification as sadness and hate were negatively correlated with the speed impression at moderate levels. The identification as sadness was also negatively correlated with the attention to other parts at a moderate level.

IV. DISCUSSION

A. Findings

The results in section III showed some differences between the student and elderly subjects on emotion evaluation of affective body motions expressed by the small-sized humanoid robot, that is, their identification of emotions for the affective body expression, body and motion parts paid their attention during the expression, and their impression of speed and magnitude of the expression. Moreover, it was shown that there were some correlations between these psychological constructs.

Almost all the student subjects identified the three types of affective body motion as the emotions intended by the motions. Moreover, many of them identified the anger and sadness motions of the robot as hate, which is an emotion proximate to anger and sadness [7]. On the other hand, many of the elder subjects did not identify these motions as either the intended ones or the proximate one. It suggests that the elder people recognize different emotions from younger people for affective body motions by robots.

Moreover, in comparison to the student subjects, more of the elder subjects paid their attentions to the upper body in the anger motion of the robot, the legs and feet in the sadness motion. These parts of the robot body are the ones not important on the affective expression implemented in the experiment. In particular, the correlation coefficient between the items of identification as anger and attention to upper body showed that identification for the anger motion of the robot was more correct as the upper body was less paid attention to.

Furthermore, in comparison with the elder subject, the student subjects more strongly felt that the magnitude of the anger motion by the robot was large, and the speed of the sadness motion was slow. The correlation coefficients showed that identification for the anger motion of the robot was more correct as the magnitude impression was stronger, and identification of the sadness motion was more correct as the speed impression was weaker. These facts suggest that differences between younger and elder people on recognition of emotions for affective body motions by robots have some relationships with those on cognitive factors for physical characteristics of robot motions, such as attention to body parts and cognition of motion speed and magnitude.

B. Implications

The experiment of the paper can be interpreted as a case study on a gap between robotics designers and users. The experimenters, who are not the elderly, implemented the affective body motions of the robot while interpreting results of the existing studies. However, the experimenters' subjective factors on affective expression, dependent on their culture, may be incorporated into the implementation process, and it may lead to the differences on evaluation of the motions between the student and elder subjects. In fact, the experimental results show that the elder subjects paid their attention to some parts of the robot body and motion which were not intended to be focused on when the affective motions were expressed.

The above interpretation has some important implications. Robotics designers using body motions as a mode of affective human-robot interaction should be sensitive for human factors for emotion recognition and their dependence on users' demographics such as age. In other words, it should sufficiently be investigated which physical characteristics can influence emotion evaluation of body motions for a specific group of users.

Moreover, the experimental results in the paper suggested age differences of emotion evaluation even in one culture. From cross-cultural perspectives, there may be several interaction effects between age, gender, and so on. If robotics designers consider multi-cultural applications of affective body motions, they should consider adaptation mechanisms for different body motion rules of emotion expression.

C. Limitations

Since we only tested with a particular type of robots with a particular interaction with subjects from specific groups, 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, the human-robot interaction in the experiment was one way from the small-sized humanoid robot to the human subjects without any context and concrete task. Thus, it did not take into account interaction effects between user demographics, contexts where robots were used, other physical characteristics of robots such as size and appearance, as dealt with in [8][9][10]. In particular, contexts of robot use, for example, domestic use for elderly care [11], may be important to validate the usefulness of body expression in interaction of robots with the elder people.

Second, the total number of subjects in the experiment was not sufficient. 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. In particular, users' cognitive characteristics should be cared since the experimental results suggest some relationships between recognition of emotions and cognition of physical characteristics of robots.

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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