ICIC Express Letters
Volume **10**, Number **6**, June **2016**
ICIC International ©2016 ISSN 1881-803X
pp. 1341–1346

EMOTIONS PERCEIVED FROM MOTIONS BY HUMAN, ANIMATION AND ROBOT

Jihong Hwang[1], Taezoon Park[2] and Wonil Hwang[2,*]

[1]Department of Mechanical System Design Engineering
Seoul National University of Science and Technology
232 Gongneung-Ro, Nowon-Gu, Seoul 01811, Korea

[2]Department of Industrial and Information Systems Engineering
Soongsil University
369 Sangdo-Ro, Dongjak-Gu, Seoul 06978, Korea
*Corresponding author: wonil@ssu.ac.kr

Received December 2015; accepted March 2016

Abstract. *Service robots are becoming popular nowadays. Prior studies related to service robots have mainly examined about appearance, facial expression, voice, gesture and motion. However, it is not clear which characteristics of service robots have an effect on affective interaction most and how they work together. This study aims to study the effects of motion media, motion size and motion velocity on the emotions invoked by the motions. The experiment was designed with 3 independent variables (motion media, motion size and motion velocity), and perceived emotions as a dependent variable. 30 participants took part in the experiment, and the results indicate that the small size of motion is preferred than the large size of motion when the motions are performed by animation and actual robots, in terms of 'favorable' and 'enjoyable' emotions. These results provide a guideline for designing the motions of service robots.*
Keywords: Perceived emotion, Affective interaction, Human motion, Robot motion

1. **Introduction.** Robots are rapidly becoming more common objects that help humans at work and/or at home these days. For instance, industrial robots play an important role in improving productivity in the manufacturing fields, whereas service robots are interacting with humans as receptionist robots in convention centers, nursing robots in hospitals, instructor robots in schools and entertaining robots in theme parks. Especially, with the rapid growth of service industry, a great deal of research has been conducted on service robots that have capabilities of social creatures. Among various capabilities of service robots, affective interaction is essential for service robots to facilitate communication between human and robots. Affective interaction of service robots includes expressing various emotions and understanding human's emotions, and it gives a better acceptance and more satisfaction of robots to human users during human-robot interaction [1]. Affective interaction between human and robots can be generally affected by several characteristics of service robots, including their appearance, facial expression, voice, gesture and motion [2-4]. It is, however, still not clear which characteristics of service robots have an effect on affective interaction most and how they work together.

This study focuses on how humans perceive the emotions from the motions of service robots in terms of motion size and motion velocity, and how the emotions perceived from the motion of service robots are different from those of human and animation as motion media. It is, in general, important to know how humans perceive the emotions from the characteristics of service robots in the aspect of affective interaction, and among various characteristics of service robots, the motion of service robots shows a dynamic characteristic of service robots compared with appearance, countenance and shapes of robots that many prior studies have examined so far [2,4]. It is also necessary to compare the emotions from the motions of service robots with those of human and animation in order to clarify the effects of motions of service robots on affective interactions. This paper is organized as follows. Related work in this section gives an overview of basic topics related to this study, and followed by a description of research methods in Section 2. Sections 3 and 4 provide the results of the experiments and discussion on the results with conclusions, respectively.

1.1. **Basic emotions.** There are many studies related to the basic emotions, which were based on the observation of human's facial expression, the action that human makes and the pattern of human's behavior. For example, Ekman et al. [5] extracted six basic emotions, i.e., anger, disgust, fear, joy, sadness and surprise, from human's facial expression. By studying human's actions, Arnold [6] suggested anger, aversion, courage, dejection, desire, despair, hate, hope, love and sadness as basic emotions, and Frijda [7] described that basic emotions included desire, happiness, interest, surprise, wonder and sorrow. By observing the pattern of human's behavior, Gray [8] suggested rage, anxiety and joy; Izard [9] mentioned anger, contempt, disgust, distress, fear, guilt, interest, joy, shame and surprise; Panksepp [10] reported expectancy, fear, rage and panic; Watson [11] mentioned fear, love and rage as basic emotions. Based on these basic emotions, service robots were designed to be able to express emotions [12], and also it was investigated what kinds of emotions could be invoked by the appearance of robots [4].

1.2. **Affective human-robot interaction.** Two issues of human-robot interaction studies are reviewed here with regard to affective interaction. What kinds of emotions can be invoked by service robots? Is it okay to use visual agent of robots instead of real prototypes when affective human-robot interaction is investigated? Regarding the emotions invoked by service robots, the appearance of service robot has been investigated as an important factor. For example, Hwang et al. [4] examined the effects of overall robot shape on emotions invoked in users, and concluded that the overall shape of robot aroused any of three emotions named 'concerned', 'enjoyable' and 'favorable', and there exists the best shape to invoke a specific emotion. In matters of visual agent for investigating human-robot interaction, there was no unanimous conclusion. For example, Bartneck [13] investigated the effects of embodiment of an emotional robot and found the effects of embodiment on the social facilitation were significant but not on the enjoyment of interaction. However, a majority of the human-robot interaction studies have still utilized a visual agent of robot, such as pictures and videos, due to its convenience. In this study, we used video clips to capture the responses of human participants.

2. **Methods.** In order to find the effects of motions by human, animation and robot on perceived emotions, the experiment was designed with 3 independent variables, i.e., motion media (human, animation and robot), motion size (large and small) and motion velocity (fast and slow), and perceived emotions as a dependent variable.

2.1. **Preparation of motions.** Before conducting the experiment, three kinds of motions were prepared in the form of video clips. First, human motions which deliver the message of greeting were recorded by a camcorder and captured by a motion capture program called 'Cortex' at the same time. 10 young (5 males and 5 females) and 6 elderly (3 males and 3 females) people performed motions to naturally express 'greeting' and 4 motions were finally selected as the appropriately combined motions with 2 types of motion size (large vs. small) and 2 types of motion velocity (fast vs. slow) through expert reviews. Second, animated motions were constructed based on the motion capture data for the 4 selected human motions. This animation process was completed through a series of conversion process with 'Motion Builder' and '3D MAX' software. Third, robot motions were performed by the actual robot that was made using an educational robot kit

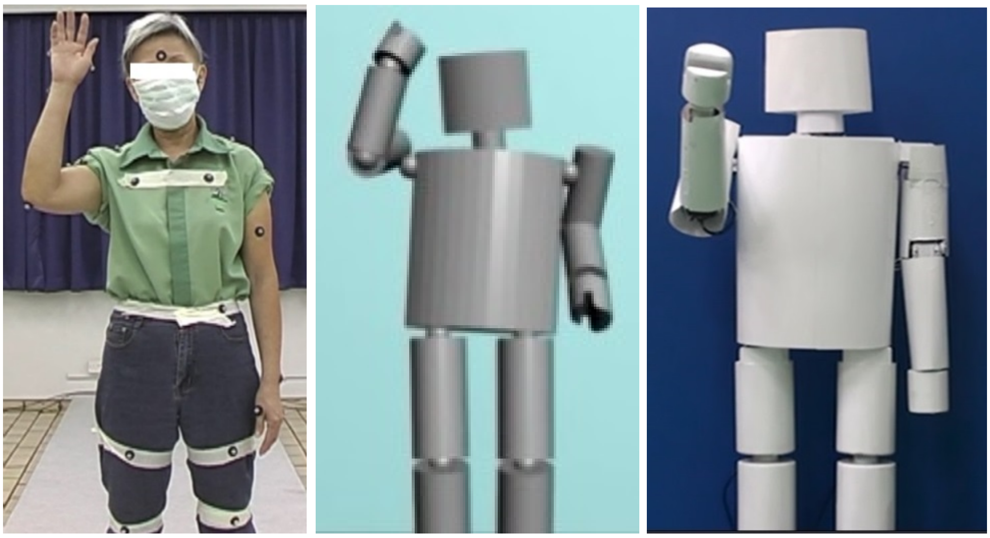

Figure 1. Motions of greeting by human, animation and robot (Left: human, Middle: animation, Right: robot)

produced by ROBOTIS Inc. (BIOLOID premium kit) and recorded by a camcorder. The appearance of the robot was almost the same as that of robot animation and its height was about 600 mm. The robot motions were created by matching their trajectory and average speed with those of the 4 selected human motions based on the corresponding motion capture data. Figure 1 shows three still images of motions performed by human, animation and robot.

2.2. **Participants.** Thirty college students participated in the experiment. Participants were 15 males and 15 females, and they were 23.5 years old on average, with a standard deviation of 3.22 years. Participants did not have any problem to watch the video clips in their eyes.

2.3. **Procedure of experiment.** Each of 30 participants was asked to answer the questionnaire after watching each of 12 motion video clips at random order. 12 motion video clips represent 12 experimental conditions (3 types of motion media (human, animation and robot) $\times$ 2 types of motion size (large and small) $\times$ 2 types of motion velocity (fast and slow)). The questionnaire includes 14 emotional expressions (see Table 1), which were used by Hwang et al. [4], to measure the agreeability of emotions invoked by motions in a 7-point scale (1: strongly disagree, ..., 4: neutral, ..., 7: strongly agree). Every participant was allowed enough time to watch the video clips and answer the questionnaire.

3. Results.

3.1. **Emotional factors.** Factor analysis using a principal component method with promax rotation was conducted to find emotional factors invoked by motions. As seen in Table 1, three emotional factors were derived and named by 'favorable', 'concerned' and 'enjoyable'. 'Favorable' factor includes relaxing, safe, pretty, accessible and amiable emotions; 'concerned' factor represents scary, dangerous and out-of-control emotions; and 'enjoyable' factor comprises interesting, amusing and exciting emotions. Embarrassing and overwhelming were excluded from three emotional factors because their values of factor loadings were not significant (< 0.6).

TABLE 1. Factor loadings for three emotional factors

Emotional expressions	Factor 1 (Favorable)	Factor 2 (Concerned)	Factor 3 (Enjoyable)	Communality estimates
Interesting	−0.1064	−0.1090	**0.9790**	0.9817
Amusing	−0.0459	−0.1192	**0.9626**	0.9428
Relaxing	**0.8030**	0.0650	0.0554	0.6521
Scary	0.0647	**0.9476**	−0.0737	0.9076
Dangerous	0.1247	**1.0269**	−0.1190	1.0843
Out of control	−0.0447	**0.8278**	−0.0463	0.6893
Embarrassing	−0.4988	0.2950	0.0709	0.3408
Overwhelming	0.1870	0.3659	0.3328	0.2796
Safe	**0.7241**	−0.1218	−0.0898	0.5472
Pretty	**0.6183**	0.0772	0.3105	0.4847
Accessible	**1.0252**	0.1097	−0.1055	1.0742
Exciting	0.1336	−0.0407	**0.6873**	0.4918
Complex	−0.3523	0.2418	0.2086	0.2261
Amiable	**0.7702**	0.0528	0.1355	0.6143
Variance explained by each factor	3.6565	2.9847	2.6754	9.3166

Notes. Factor loadings (> 0.6) in bold type were considered to be significant. Three factors explained 66.5% of total sample variance.

TABLE 2. ANOVA results for three emotional factors

Variables	Favorable	Concerned	Enjoyable
Motion media	F(2,348) = 6.96, p = 0.0011**	F(2,348) = 2.09, p = 0.1260	F(2,348) = 0.52, p = 0.5980
Motion size	F(1,348) = 46.04, p < 0.0001**	F(1,348) = 0.00, p = 1.0000	F(1,348) = 26.80, p < 0.0001**
Motion velocity	F(1,348) = 0.29, p = 0.5930	F(1,348) = 0.00, p = 0.9750	F(1,348) = 0.81, p = 0.3680
Motion media × Motion size	F(2,348) = 16.30, p < 0.0001**	F(2,348) = 1.14, p = 0.3220	F(2,348) = 12.38, p < 0.0001**
Motion media × Motion velocity	F(2,348) = 0.90, p = 0.4074	F(2,348) = 0.17, p = 0.8420	F(2,348) = 0.24, p = 0.7830
Motion size × Motion velocity	F(1,348) = 0.80, p = 0.3732	F(1,348) = 0.55, p = 0.4600	F(1,348) = 1.56, p = 0.2120
Motion media × Motion size × Motion velocity	F(2,348) = 0.27, p = 0.7604	F(2,348) = 0.14, p = 0.8700	F(2,348) = 0.10, p = 0.9090

Notes. **: p < 0.01

3.2. **ANOVA results for three emotional factors.** Analysis of variance (ANOVA) was conducted to investigate the effects of motion media, motion size and motion velocity on three emotional factors. Table 2 summarizes ANOVA results for three emotional factors. First, motion media ($F(2,348) = 6.96$, $p = 0.0011$) and motion size ($F(1,348) = 46.04$, $p < 0.0001$) are significant main effects for 'favorable' emotional factor, and there is a significant interaction effect between motion media and motion size for 'favorable' emotional factor ($F(2,348) = 16.30$, $p < 0.0001$). Specifically, human motion (4.50) invokes more favorable emotion than motions performed by animation (3.98) and actual robot (3.98), and the small size of motion (4.60) invokes more favorable emotion than the large

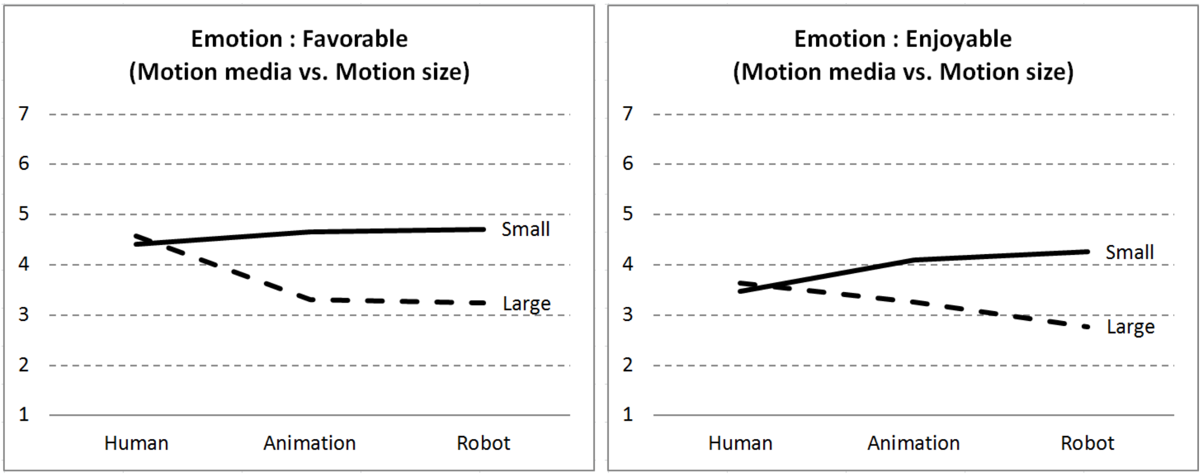

Figure 2. Interaction plots between motion media and motion size for 'favorable' and 'enjoyable' emotional factors (Left: 'Favorable' factor, Right: 'Enjoyable' factor)

size of motion (3.71). As seen in the left plot of Figure 2, the small size of motion invokes more favorable emotion than the large size of motion when the motions are performed by animation and actual robot, but it is not the fact when the motion is performed by human.

Second, there is no significant main or interaction effect for 'concerned' emotional factor. Third, motion size is a significant main effect for 'enjoyable' emotional factor ($F(1,348) = 26.80$, $p < 0.0001$), and there is a significant interaction effect between motion media and motion size for 'enjoyable' emotional factor ($F(2,348) = 12.38$, $p < 0.0001$). Specifically, the small size of motion (3.94) invokes more enjoyable emotion than the large size of motion (3.23). As seen in the right plot of Figure 2, the small size of motion invokes more enjoyable emotion than the large size of motion when the motions are performed by animation and actual robot, but it is not the fact when the motion is performed by human.

4. **Conclusions and Discussion.** From the experiments, we investigated the effects of motion media, motion size and motion velocity on the emotions perceived from the motions. It is concluded from the experimental results that people prefer human motions rather than motions performed by animation and actual robots, in terms of 'favorable' emotion, and the small size of motion is preferred than the large size of motion when the motions are performed by animation and actual robots, in terms of 'favorable' and 'enjoyable' emotions. The velocity of motion is not significant for any of invoked emotions. These results indicate that people would feel more favorable and enjoyable emotions if we design the relatively small size of motions compared to human motions when designing the motions of service robots. In addition, when we try to study the effects of motions we can consider using animation of robot instead of actual robots for cost efficiency, because the experimental results show very similar patterns of effects between animation and actual robots. For further study, we need to study various motions for more generalized conclusions because this study focused only on the motion of 'greeting'. We also need to consider the effects of demographic variables on the emotions invoked by robot motions. For example, gender or age could have different effects on the emotions.

REFERENCES

[1] R. Kirby, J. Forlizzi and R. Simmons, Affective social robots, *Robotics and Autonomous Systems*, vol.58, pp.322-332, 2010.

[2] J. Goetz, S. Kiesler and A. Powers, Matching robot appearance and behavior to tasks to improve human-robot cooperation, *Proc. of the 12th IEEE International Symposium on Robot and Human Interactive Communication*, pp.55-60, 2003.

[3] C. L. Nehaniv, K. Dautenhahn, J. Kubacki, M. Haegele, C. Parlitz and R. Alami, A methodological approach relating the classification of gesture to identification of human intent in the context of human-robot interaction, *Proc. of the 14th IEEE International Symposium on Robot and Human Interactive Communication*, pp.371-377, 2005.

[4] J. Hwang, T. Park and W. Hwang, The effects of overall robot shape on the emotions invoked in users and the perceived personalities of robot, *Applied Ergonomics*, vol.44, pp.459-471, 2013.

[5] P. P. Ekman, V. W. Friesen and P. Ellsworth, What emotion categories or dimensions can observers judge from facial behavior? in *Emotion in the Human Face*, P. Ekman (ed.), Cambridge University Press, New York, 1982.

[6] M. B. Arnold, *Emotion and Personality*, Columbia University Press, New York, 1960.

[7] N. H. Frijda, *The Emotions*, Cambridge University Press, New York, 1986.

[8] J. A. Gray, *The Neuropsychology of Anxiety*, Oxford University Press, Oxford, 1982.

[9] C. E. Izard, *The Face of Emotion*, Appleton-Century-Crofts, New York, 1971.

[10] J. Panksepp, Toward a general psychobiological theory of emotions, *Behavioral and Brain Sciences*, vol.5, pp.407-467, 1982.

[11] J. B. Watson, *Behaviorism*, University of Chicago Press, Chicago, 1930.

[12] C. Breazeal, A. Takanishi and T. Kobayashi, Social robots that interact with people, in *Springer Handbook of Robotics*, B. Siciliano and O. Khatib (eds.), Springer-Verlag Berlin Heidelberg, 2008.

[13] C. Bartneck, *eMuu – An Embodied Emotional Character for the Ambient Intelligent Home*, Ph.D. Thesis, Technische Universiteit Eindhoven, Eindhoven, Duitsland, 2002.