

Research Article

Physiological Responses on Greeting with Robot under Difference of Culture

Hiroataka Aoki,¹ Yasunari Fujimoto,¹ Satoshi Suzuki,² Eri Sato-Shimokawara,¹ and Toru Yamaguchi³

¹Graduate School of System Design, Tokyo Metropolitan University, 6-6 Asahigaoka, Hino, Tokyo 191-0065, Japan
²Department of Robotics and Mechatronics, Tokyo Denki University, 2-2 Kanda-Nishiki-cho, Chiyoda-ku, Tokyo 101-8457, Japan
³Information and Communications Systems Engineering, Tokyo Metropolitan University, 6-6 Asahigaoka, Hino, Tokyo 191-0065, Japan
Address correspondence to Hiroataka Aoki, aoki-hiroataka@sd.tmu.ac.jp

Received 3 July 2011; Revised 8 February 2012; Accepted 12 March 2012

Abstract In this study, authors suggested the system which considered difference of culture through the language and gesture movement in the interaction with a robot when user greets. In the interaction, verbal and nonverbal information are important to do natural communication. Authors focused on not only languages but also gesture movement which varies from cultures. It is necessary for even communication between a human and a robot to take in the difference of culture. Authors' experiment shows that whether this greeting difference leads to changes or not in the human biological signal. The human biological signals are estimated by pulse wave obtained from a finger and brain blood flow measured by NIRS. The result is that biological signals will be changed when the reaction of languages and gestures changed.

Keywords interaction robot; culture; pulse wave; brain blood flow

1 Introduction

Products vary from area to area and country to country; such as the function, method of use, and the design. It evolved originally from the culture. This is probably based on cultural differences and cultural values; such as history, customs, traditions, religion and climate. Therefore, it is necessary to design a kind of product according to culture of the country. A reception according to the culture is also necessary in the interaction between a human and a human. For example, the concierge reception services will improve the customer service in the country's cultural guide for the visitors. There are two kinds of modals in interpersonal communication-verbal and nonverbal. Verbal means that the information is transmitted by the language, and nonverbal means that the information is transmitted to the dialogist by the gesture or by the distance between the dialogist. For example, Table 1 shows personal space. Personal space is defined by hall divided into four parts (intimate, personal, social and public space) [3]. When someone goes

into personal space, people will feel discomfort or have psychological effects. In Japanese, Sato is validated for the Japanese personal space and can be seen that the definition is different from Hall [1].

So, different countries have different cultures. Gesture will not be transmitted if it catches in the wrong meaning by receiver. It is also important that robot take in dynamic information for communication with human [7]. Although the human performed it implicitly, the interaction with a robot is necessary to be developed. Therefore, it is imperative to make the modeling that can describe the difference caused by the culture. In the communication between a human and a robot, it can be deepened communication by appropriate utterance and movement. Especially, greeting is an important act of making an opportunity to start communication. Greeting differs from language, gesture, and personal space.

Authors proposed the greeting system which made use of differences of cultures language and gesture during the human-robot interaction. Authors' experiment shows that whether this greeting difference leads to changes or not in the human biological signal. Technically, author judged it by human stress and brain activity. From these two approaches, author is able to show the difference that is measured quantitatively.

2 Interaction robot for greeting with visitor's cultures

This interaction robot for greeting system consists of image and voice processing as shown in Figure 1.

The interaction robot used in this system base upon "ApriPoco" made by Toshiba Corp. ApriPoco has four

Table 1: Personal space [3].

	Intimate	Personal	Social	Public
USA	0 ~ 45	45 ~ 120	120 ~ 360	360 ~ 760
Japan	m: 60, w: 58	m: 72, w: 69	m: 89, w: 107	m: 108, w: 118

Unit: cm, m: man, w: woman.

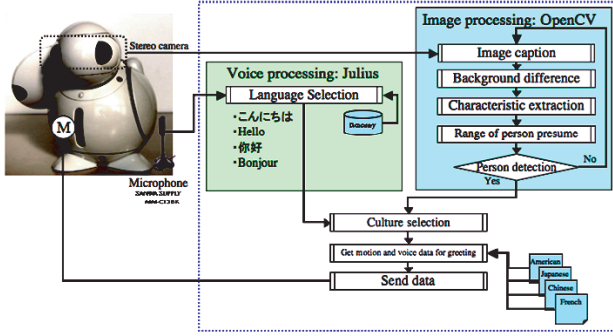
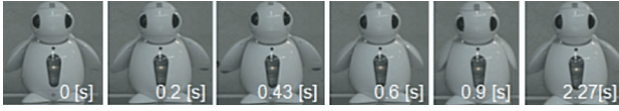


Figure 1: Interaction robot for greeting with visitor's culture.



(a) Japanese greeting.



(b) English and Chinese greeting.



(c) French greeting.

Figure 2: Motion of ApriPoco's greeting.

movable components: the head, the arms, and the waist. The size was $210 \times 210 \times 270$ mm. ApriPoco also has the voice recognition, the utterance function, and the stereo camera device. Picture processing uses OpenCV [10]. Stereo camera of ApriPoco detects a human by characteristic point extraction. Voice processing uses Julius [6]. The greeting words of four national languages, Japanese, English, Chinese, and French, will be recognized. The robot detects his/her culture from the greeting word. And then, get motion and voice data for greeting from database, ApriPoco returns in the appropriate language with motion. Figure 2 shows robot motions which depend on each culture. Japanese greeting lower the head like a bow; English and Chinese greeting raises the arm like "hi"; French greeting raises the arm twice like handshake. These motions are imitated to ApriPoco.

3 Interaction experiment

3.1 Biological signal measurement

Human biological signal will be changed when the tester in the experiment become uncomfortable [5]. In this

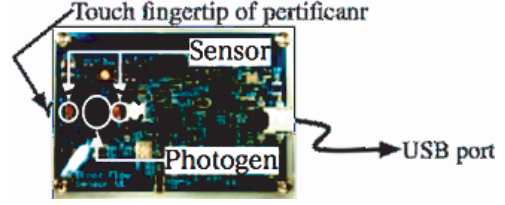


Figure 3: Pulse wave sensor.

experiment, human biological signal will be measured when ApriPoco greets by three languages (Japanese, Chinese, and French). The result determines whether differences caused by native or foreign languages and gestures, and what can be known to quantify the differences. Participants in this experiment consisted of Japanese and Chinese. Biological signal is going to be measured by pulse wave and brain blood flow.

3.1.1 Pulse wave

Pulse wave showed the information which is obtained from mood and stress. A method for evaluating stress has been studied to analyze the measures of peripheral physiological responses. In this experiment, pulse wave is obtained from a finger (Figure 3). Pulse wave at the fingertip was tested through an infra-red sensor which need to attach the sensor plate to the finger in order to measure health status and heartbeat of the participant. The sensor is able to measured at 0.01 second. Mental stress level is analyzed by Trajectory Parallel Measure Method and the distance between the trajectories through the local space based on chaos theorem [2]. Chaos evaluation Ec is calculated by the following equation:

$$Ec = h_f / dr. \quad (1)$$

Value h_f is frequency less than threshold f . Value dr means the trajectory distance rate through local space. There is a stress when Ec is high.

3.1.2 Brain blood flow

When people saw the body movements of others, it is known that "mirror-neuron" increased activity of neuronal group. Brain blood flow is measured by near-infrared spectroscopy (NIRS). The NIRS is robust against electrical noise because of laser measurement, and allows it to measure the brain activation of natural behavior in a nonrestrictive environment, such as speaking [4], reading [9], and language recognition [11]. NIRS can measure areas around frontal cortex relatively favorably, where a "mirror-neuron" property exists in a primary motor cortex (M1) and Brodmann area 44 (BA44) [8]. Four channels around M1 and two channels near the right and left BA44 were investigated (Figure 4).

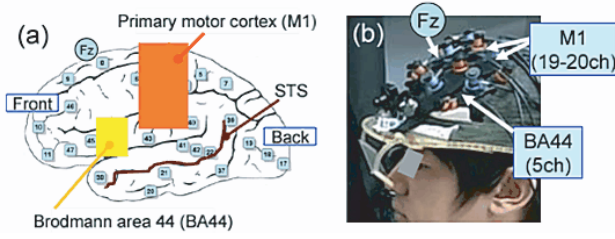


Figure 4: Sensing position.

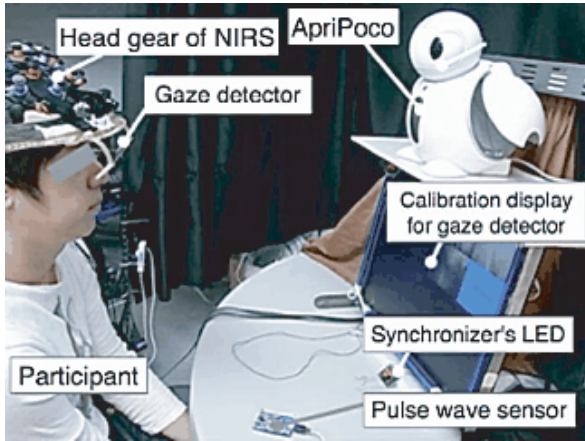


Figure 5: Experiment scene.

3.2 Experimental system

The experimentation measures human biological signal when tester greets with three kinds of cultures. The subject of Greeting is going to greet with three kinds of cultures. We used ApriPoco as the subject in this experiment. The ApriPoco speaks three languages. For quantitative analysis of the country-by-country difference against greeting action, the measurement system that is able to collect the following information and signals (Figure 5):

- Brain blood flow (by ETG-4000, Hitachi Medical Corporation, Japan).
- Eye-ball image for the gaze analysis (by the developed gaze detector).
- 3-axis acceleration of the head motion (by MVP-RF-AC, MicroStone Corp. Japan).
- Pulse wave in blood vessels (by the developed device).
- Motion picture of participant (by the developed HDD recording system [12]).

Gaze is useful for the communication analysis since the gaze motion reflects the user's internal status on real-time. In this experiment, a headgear as the gaze detector was improved so as to be used with the NIRS measurement simultaneously. Since unconscious reaction such as nodding and tilting is also important for communication analysis, an acceleration of the head was measured by the wireless sensor system. The

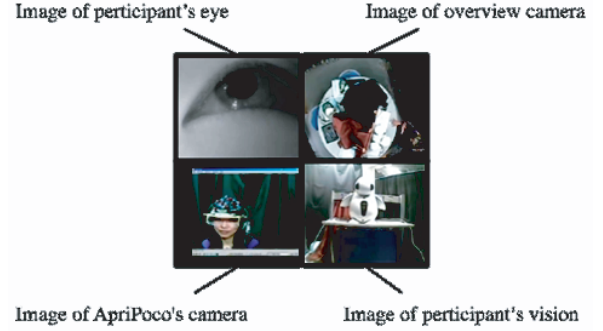


Figure 6: Captured image of surveillance monitor.

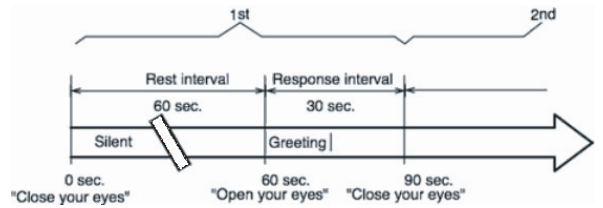


Figure 7: Task sequence.

participant sat on a chair in front of the robot, faced the robot and greeted it. During this process the above-mentioned signals were measured. In this paper, the pulse wave and NIRS mainly dealt with the analysis. Participant's eye movement, overview camera (attached to the ceiling), ApriPoco's eye camera, and participant's vision were recorded (Figure 6).

3.3 Experimental task

The experiment in this section was a preliminary one to check the possibility of the measurement which is to distinguish the country-by-country difference. Because the purpose is not statistical validation, experiments to a few participants were performed. Participants consisted of seven male Japanese, three male Chinese, and one female Chinese. (She has Taiwanese nationality, but she speaks Chinese as same as the Chinese people. So this participant is called Chinese to avoid misunderstanding in later discussion). Age of participants is twenties. Three types of greeting, Japanese, Chinese, and French styles, were programmed to ApriPoco using the utterance function and motion control. French was chosen because the language was non-native for all the participants. Since we know empirically that impression of greeting differs from gesture greeting and voice greeting, these two patterns were performed by ApriPoco.

Figure 7 shows time sequence of one cycle. One cycle is performed in 90 seconds. First 30 seconds is silent or random utterance. This period of time is rest interval to relax or random utterance. The meaning of random utterance is to start speaking meaningless word from 3 to 6 characters by ApriPoco. It was performed for giving light stress or receiving the greetings from meaningless word. Participants' eyes

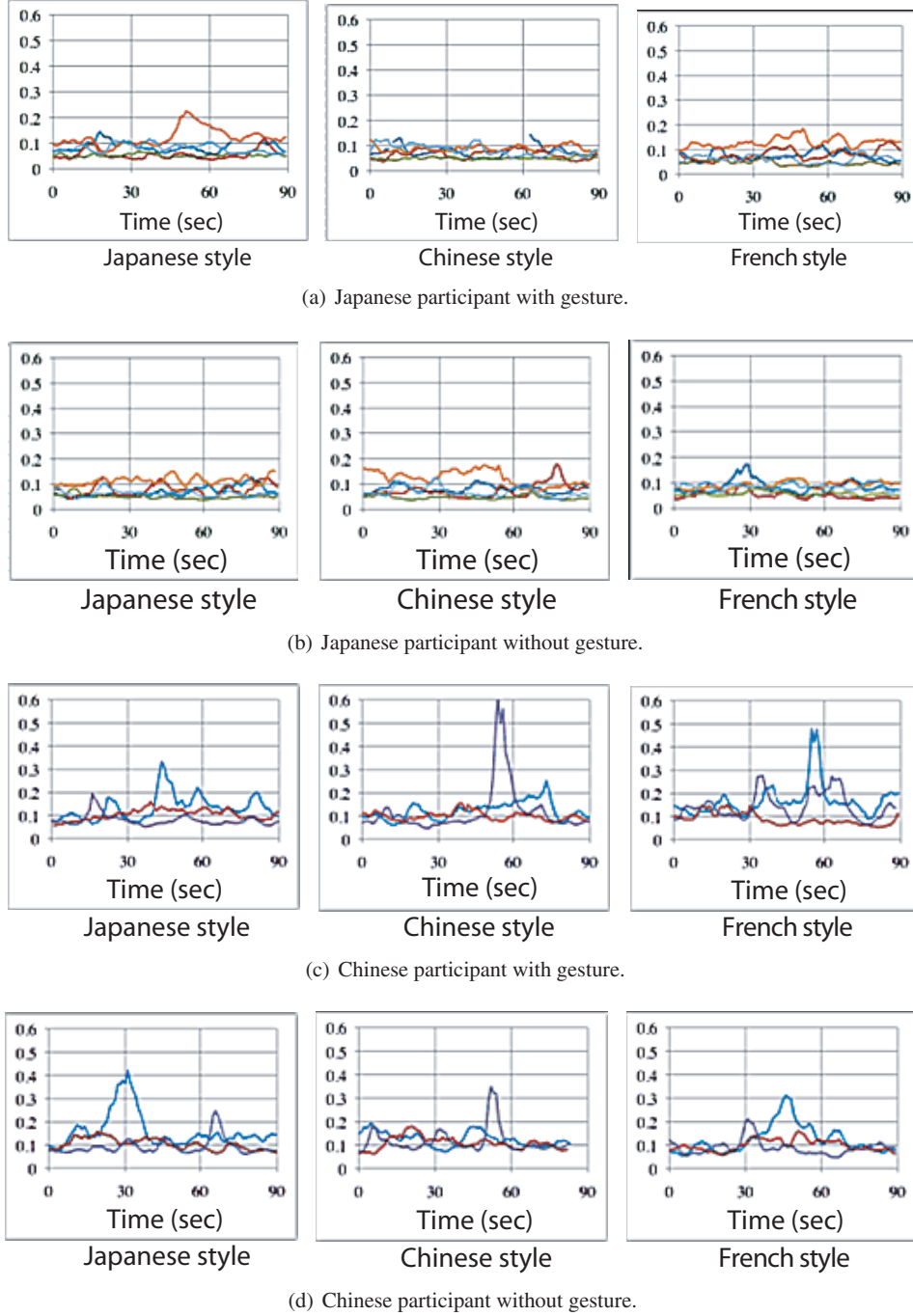


Figure 8: Results Ec of pulse wave analyzer to chaos.

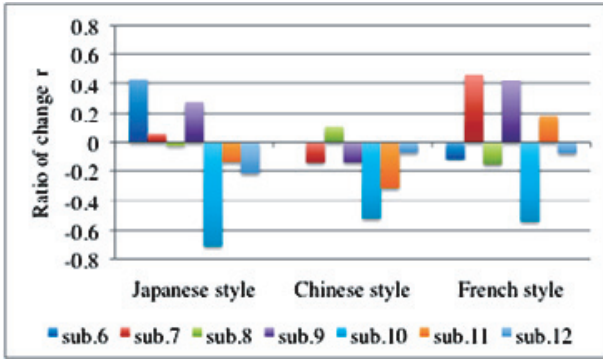
are closed in order to suppress needless visual processing in the brain. 30 seconds later, participants are required to open their eyes, and ApriPoco start to greet with gesture or without gesture. After that, it continues the same situation (silent or random utterance) again. Combination of greeting is 12 patterns in all; silent or random utterance, with the gesture during greeting or without the gesture, and speak three languages. The total time was $(90 + 30) \times 12 \text{ sec} = 24 \text{ mins}$ for each participant. It is desired that the total time

of this experiment is less than 30 minutes since long time measurement would bring participants fatigue.

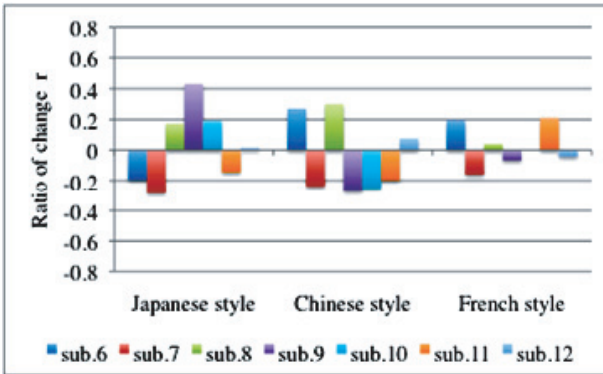
4 Result and discussions

4.1 Pulse wave

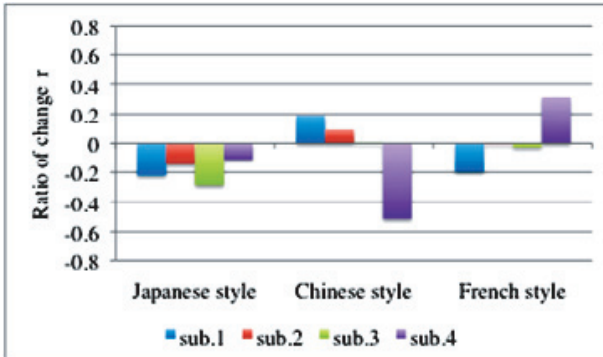
Figure 8 shows that the results Ec of pulse wave analyzer to chaos. The parameters are that length of time-series is 600 (6 seconds), dimension of embedding is three, delay step of embedding is one, number of neighborhood to calculate



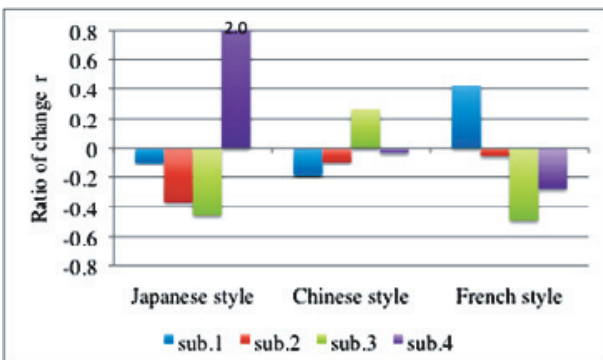
(a) Japanese participant with gesture.



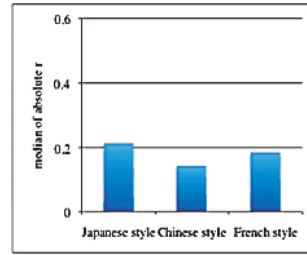
(b) Japanese participant without gesture.



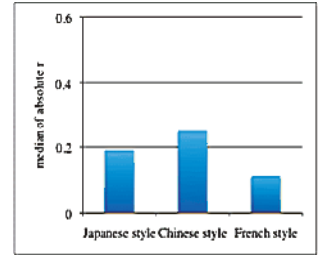
(c) Chinese participant with gesture.



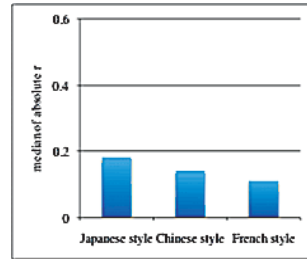
(d) Chinese participant without gesture.

Figure 9: The change rate r from rest interval.

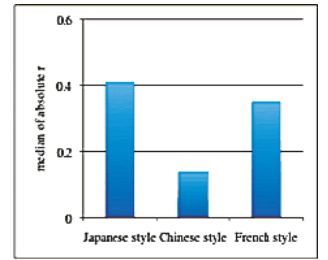
(a) Japanese participant with gesture



(b) Japanese participant without gesture



(c) Chinese participant with gesture



(d) Chinese participant without gesture

Figure 10: Medians of absolute r .

parallelism in local space is three, and threshold f is 0.01. Figure 9 shows that the comparison of the change rate from rest interval. Proportion of the variation r is calculated by the following equation:

$$r = (Ec_{66} - Ec_{59}) / Ec_{59}, \quad (2)$$

where Ec_{59} is the chaos analysis of just before greeting, and Ec_{66} is analysis of the chaos. So, r shows the percentage of change from resting. The absolute value of the change rate is calculated, and Figure 10 shows the comparison of medians.

In the case of Japanese, there is a reaction caused by native language greeting regardless of gesture. On the other hand, there is a different reaction caused by different culture greeting. In the case of Chinese, the same as the Japanese case, there is apparent reaction which was caused by native language greeting regardless of gesture. But there is also a strong reaction that different culture greeting without gesture.

In sum, Japanese and Chinese participant have similar responses to native language greeting regardless of gesture.

4.2 Brain blood flow

Figure 11 shows an example of time response to the total Hb of M1. On each graph, the total Hb levels of each four channel corresponding to the M1 area are plotted. The red line represents right hemisphere and the blue line represents left hemisphere. Almost all the graphs indicate that each total Hb decreased in the response interval, and it can be guessed that some response corresponding to the greeting stimulus can be detected according to the NIRS data. When

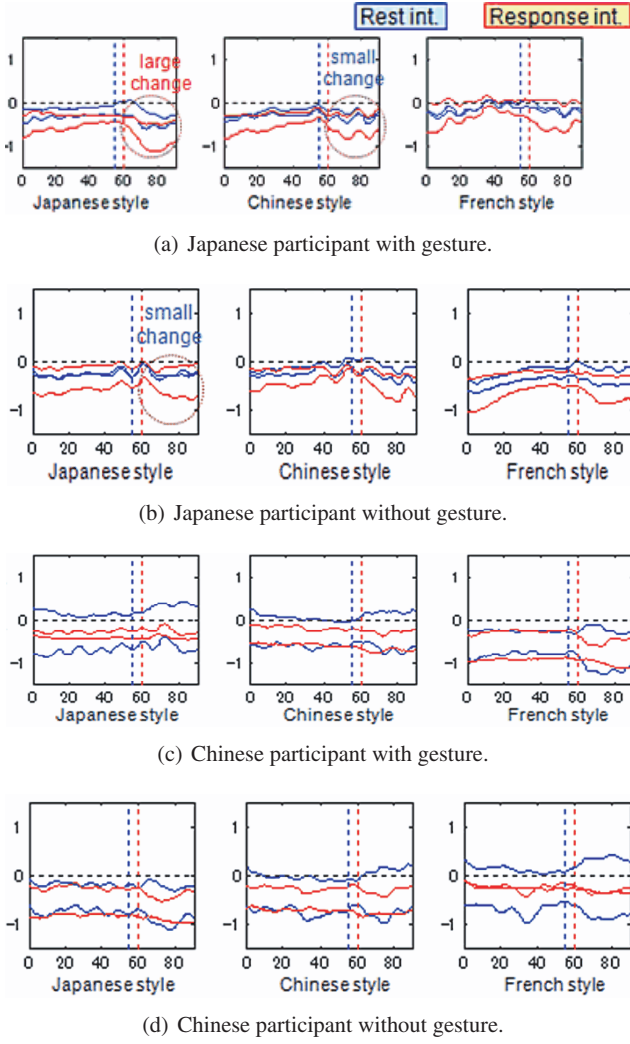


Figure 11: Changes of the total Hb at M1.

Japanese participant watched Japanese greeting, the change in the response interval in the case of “without gesture” was smaller than the “with gesture” case.

Conversely, in the case of “with gesture and by non-native language,” the change was small; hence, it appears that there is a tendency which is determined by the gesture type and the greeting style.

Figure 12 shows that comparison of fluctuating ranges. This graph is to remove the bias as the average 10 seconds before greeting.

In the case of Japanese, when participants greeted by native language with gesture, bar change more apparent than other language (label F1). However, when there is no gesture, it did not change (label F2). According to an assumption of a mirror neuron, it can be thought that a motion that is familiar to an animal which induces stronger activation in a mirror neuron; hence, the Japanese participant might feel unfamiliar to the ApriPoco’s gesture.

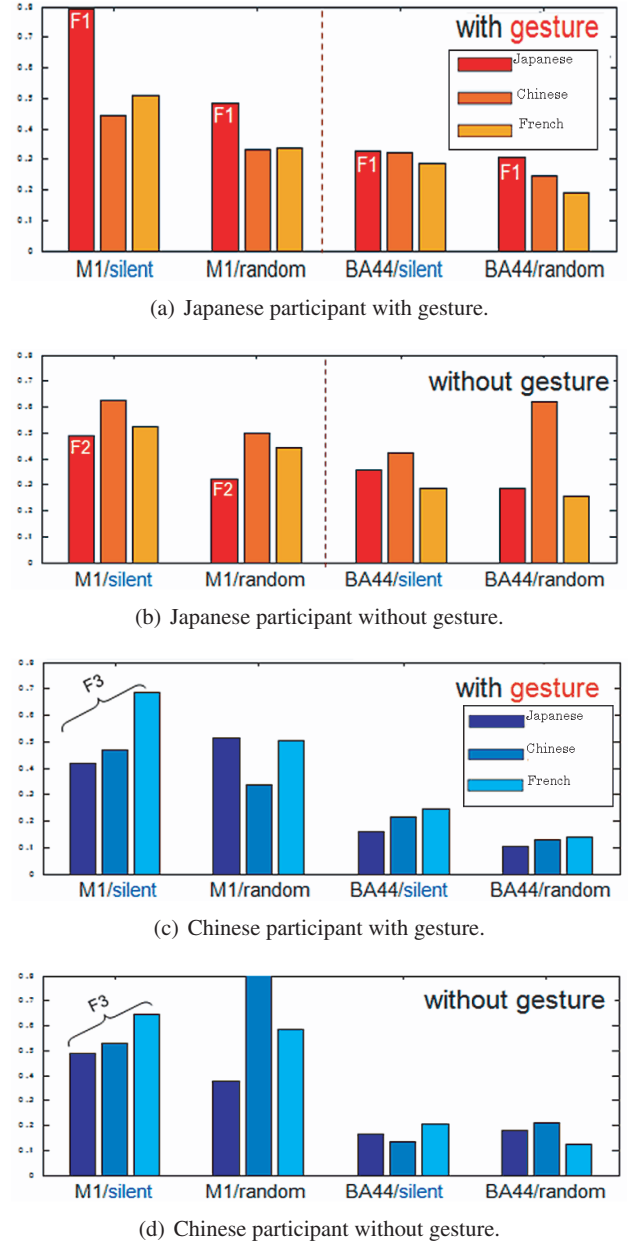


Figure 12: Results of brain blood flow.

In the case of Chinese, a magnitude relation is Japanese < Chinese < French. This indicates that Chinese participant did not feel different about the robot greeting styles (label F3). It was also difficult to find particular characteristics against native language.

5 Conclusion

In this study, authors proposed that the greeting system has cultural differences of language and gesture during the human-robot interaction. In the experiments, human biological signals were measured when robot greets by different languages and gesture. According to the results of pulse wave analyzer to chaos, Japanese and Chinese participants

will make similar responses to native language greeting regardless of gesture. And it is different from non-native language. According to the results of brain blood flow, Japanese participant will react by native language with gestures, but Chinese participant will not react abnormally by languages or gestures. As a result, different biometric signals were detected in the different reaction of languages and gestures.

Because there are few participants in this experiment, authors are not able to conclude that the difference is definitely caused by country yet. Of course it is probably caused by the individual differences, and caused by biometric signals, in the reaction of native and other languages with gestures. And there is a need to consider the participants sex or age. In addition, this robot has less flexibility of joints, may not be enough to express the gesture. Therefore, the greetings with the robot might not so much naturally that is equal to a human being.

In the future, with the number of participants increasing, and a native voice being used in the experiments, authors will clarify the differences caused by country. In addition, it is necessary to compare it with the case for natural human greets.

Acknowledgments NIRS is held by Suzuki laboratory, Tokyo Denki University. This experiment is being conducted as a part of JST project.

References

- [1] S. Ayako, *How Do You Express Yourself*, Kodansha, 1995.
- [2] Y. Fujimoto and T. Yamaguchi, *Evaluation of mental stress by analyzing accelerated plethysmogram applied chaos theory and examination of welfare space installed user's vital sign*, in Proceedings of the 17th World Congress the International Federation of Automatic Control (IFAC/08), 2008, 8232–8235.
- [3] E. T. Hall, *The Hidden Dimension*, Anchor, New York, 1990.
- [4] M. J. Herrmann, A. C. Ehlis, and A. J. Fallgatter, *Frontal activation during a verbal-fluency task as measured by near-infrared spectroscopy*, Brain Res Bull, 61 (2003), 51–56.
- [5] A. Honda, H. Masaki, and K. Yamazaki, *Reaction specificity of autonomic nerve system for positive and negative emotion inducing stimulus*, Waseda Human Science Research, 8 (1999), 75–86.
- [6] Julius, <http://julius.sourceforge.jp/index.php>.
- [7] T. Kurokawa, *Nonverbal interfaces and perspective of them in the near future*, IEICE, 100 (2000), 49–54.
- [8] N. Nishitani, M. Schürmann, K. Amunts, and R. Hari, *Broca's region: from action to language*, Physiology, 20 (2005), 60–69.
- [9] Y. Noguchi, T. Takeuchi, and K. L. Sakai, *Lateralized activation in the inferior frontal cortex during syntactic processing: event-related optical topography study*, Hum Brain Mapp, 17 (2002), 89–99.
- [10] OpenCV, <http://opencv.willowgarage.com/wiki/>.
- [11] M. Peña, A. Maki, D. Kovacic, G. Dehaene-Lambertz, H. Koizumi, F. Bouquet, et al., *Sounds and silence: an optical topography study of language recognition at birth*, Proc Natl Acad Sci U S A, 100 (2003), 11702–11705.
- [12] S. Suzuki, K. Kuronuma, and F. Harashima, *Development of gaze detection system for multiple users – toward realization of an intelligent service interface*, in Proc. of ICROS-SICE Int. Joint Conf., Fukuoka International Congress Center, Japan, 18–21 August 2009, 3245–3250.