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Pseudo-haptic by stereoscopic images and effects on muscular activity

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Abstract

The authors have been conducting research on cross-modal perception employing sensory integration in which participants perceive tactile sensation from stereoscopic (3D) images. The pseudo-haptic system enables the phenomenon of subtle tactile sensation by spatial and temporal synchronization with 3D images without any physical contact.

In this study, a 3D image of an object was presented using a binocular see-through head-mounted display, and participants moved their forearms as if touching the viewed object. Myoelectric potentials were measured during experiencing a subtle tactile sensation by the forearm movements. From the results of the experiment, a decrease of myoelectric potential and extension of movement time were found with increase of intensity of the pseudo-haptic sensation.

Background

With the development of technologies associated with virtual reality (VR), augmented reality (AR), and mixed reality (MR), attention has focused on user interfaces for stereoscopic (3D) images. In particular, AR and MR systems have been proposed in which interaction occurs by the user touching a virtual object with their own hand, such as HoloLens (Microsoft) [1]. Various methods have also been proposed for feedback of the sense of touch, the authors have studied tactile information by visual stimulation, focusing on pseudo-haptic.

Pseudo-haptic is a tactile illusion, unlike haptic which provides tactile feedback by applying a force or vibration to the user. Pseudo-haptic is classified as one concept for providing cross-modal information, in which certain sensation is supplemented by other sensory information.

Pseudo-haptic by 3D images

The authors focused on a cross-modal system using 3D images inspired by the rubber hand illusion. The rubber hand illusion is one illusion in which an object that is separate from the parts of one's body is perceived to be a part of one's own body [2].

The authors carried out experiments to reproduce the rubber hand illusion in virtual space, as a pilot cross-modal system using 3D images [3]. Figure 1 shows the experimental setup for the rubber hand illusion, and Figure 2 shows the pilot system constructed by the authors. In this system the actual hand of the participants was hidden by the 3D display, and a CG hand model was presented in the same position. An oscillator was attached to the actual hand, and a CG object attached to the CG model was presented as vibrating synchronously with the motion of the oscillator.

Then the authors have induced the body image using the cross-modal system, and applied it to safety education using simulated experience of mock accidents [4], evaluated the strength of the illusion using brain activity measurement [5], etc.

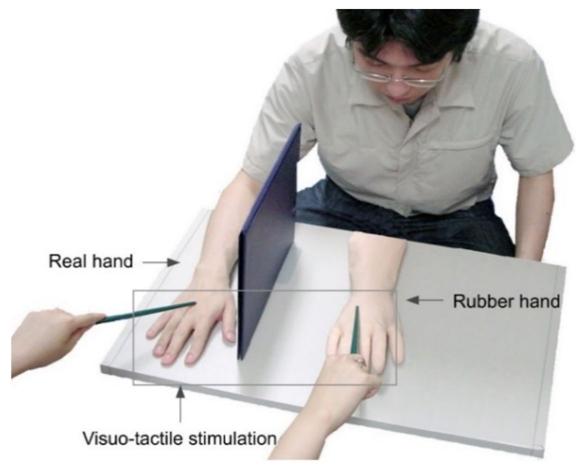

Figure 1. Rubber hand illusion experiment

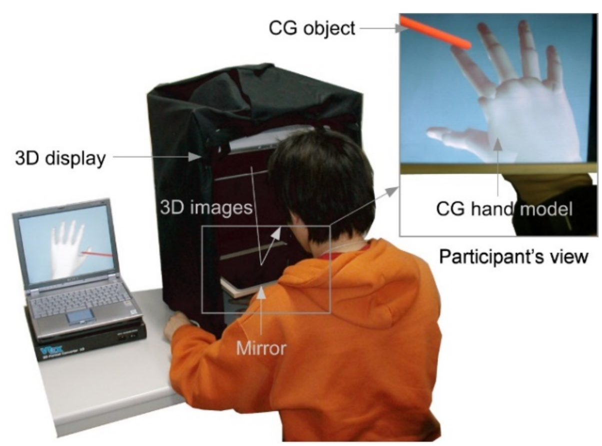

Figure 2. Pilot cross-modal system

In recent years the authors have proposed a pseudo-haptic system that induces subtle tactile sensations, using 3D images presented by a binocular see-through head-mounted display (HMD). In the system, the participant wears a binocular see-through HMD, and a 3D image of an object floating within a reachable distance becomes visible. The participant places his or her hands as if touching the viewed object to be observed resting on the hands. By adjusting the hands to feel the object touch the palms, then with a slow-speed motion of the head or object is perceived, and the participant experience a subtle tactile sensation such as a slight breeze or a cool or warm sensation [6]. Figure 3 shows the basic layout of the system.

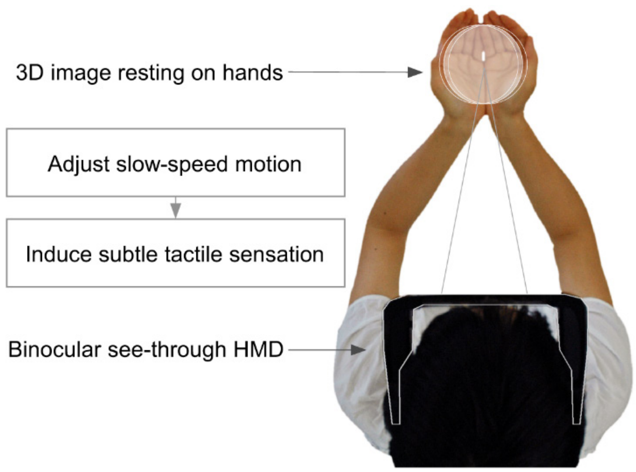

Figure 3. Basic layout of the proposed pseudo-haptic system

Objectives

Although various representations and applications are expected by the pseudo-haptic system using 3D images, it is necessary to understand the basic characteristics. Therefore, the current issue is how to evaluate the intensity and the characteristics of the subtle tactile sensation.

In this research, the objective was to evaluate the pseudo-haptic system from the point of view of the action of touching a virtual object. Specifically, a white sphere generated by CG (hereafter referred to as "sphere") was presented as the virtual object, objective evaluation was carried out by measuring myoelectric potentials when pushing the sphere with the palm, and results of subjective evaluation were also analyzed.

Methods

Experimental layout

Using a see-through HMD (MOVERIO BT-200, Epson), the sphere was presented to the participants about 40 cm before their eyes as the virtual object.

The participants observed the sphere using a chin support placed on a table. A gesture recognition device (Leap Motion) was placed on the table, and the position of the hand of the participants was detected.

The sphere presented by the see-through HMD was generated and controlled by a game engine (Unity), and connected to the gesture recognition device via a Windows PC. The experimental layout is shown in Figure 4.

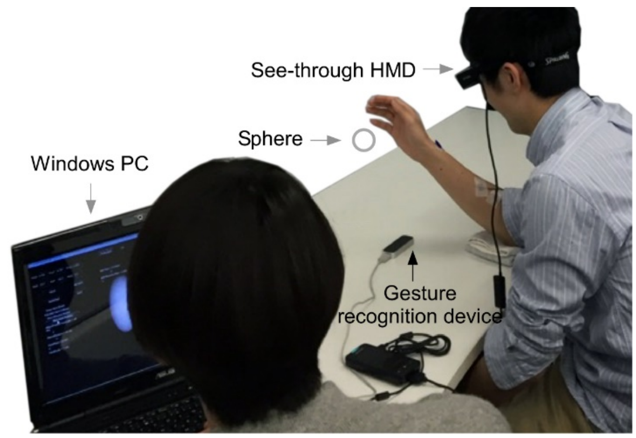

Figure 4. Experimental layout

Experimental task

The action of pushing the sphere was set as the experimental task. Specifically, the participants were required to carry out a series of actions in which the sphere was pushed with the right palm to the left and back, repeated 10 times under each experimental condition.

The hand motions of the participants were measured by the gesture recognition device, and interaction was generated in which the sphere was moved in accordance with the motions of the palm.

Experimental conditions

In the experiment, the following 4 conditions were set. The CG hand model was used as a cue for judging contact between the palm of the participant and the sphere.

- Condition 1 was a control condition in which the hand motions were measured, without presenting the sphere and CG hand model.
- Condition 2 was a condition in which the sphere was presented but the CG hand model was not presented, and when there was contact interaction.
- Condition 3 was a condition in which presentation of the CG hand model was added to Condition 2.
- Condition 4 was a condition in which, in Condition 2, where was no interaction during contact.

Figure 5-8 shows the participant's view under each condition.

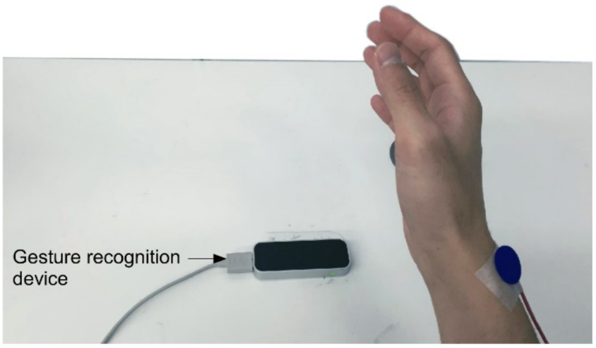

Figure 5. Participant's view under Condition 1

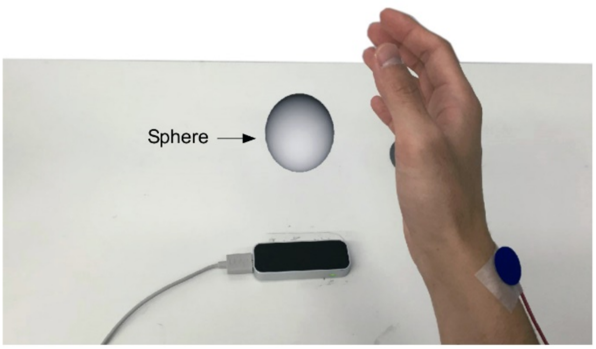

Figure 6. Participant's view under Condition 2

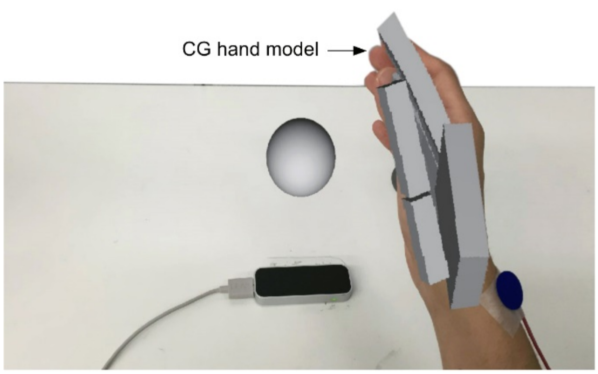

Figure 7. Participant's view under Condition 3

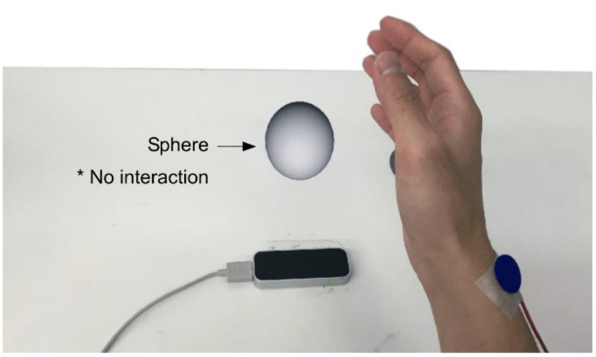

Figure 8. Participant's view under Condition 4

Measurements

The myoelectric potentials during a task were measured using a bioamplifier (Neuropack μ, Nihon Kohden), as an objective index. Two measurement positions were selected from their relevance to the experimental task, the extensor digitorum which dorsiflexes the hand joint, and the flexor carpi radialis muscle which causes inward rotation of the forearm. Figure 9 shows the positions of the electrodes.

As subjective indexes, psychological responses were obtained for the following 4 items in 7 levels using a questionnaire;

- Question 1 "Did the sphere appear to be actually present?"
- Question 2 "Did it feel like you were touching the sphere with your hand?"
- Question 3 "When you pushed the sphere, did you feel a reaction force?"
- Question 4 "Was there any change in your hand motion and the force between the condition when the sphere was presented and the condition when it was not presented?"

The subjective indexes were not measured for Condition 1 when the sphere was not presented.

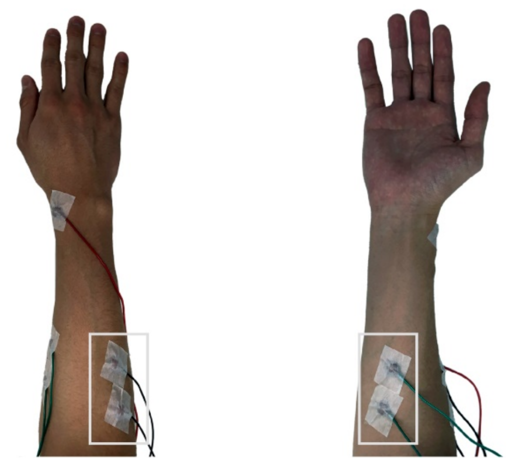

Figure 9. Positions of extrudes (left; extensor digitorum, right; flexor carpi radialis muscle)

Participants

The participants were 14 males and females in their 20s with normal binocular vision. Informed consent was obtained in writing from all the participants in advance.

After the participants practiced the experimental task, Condition 1 was carried out. Then the remaining 3 conditions were carried out in a random order, and responses to the questionnaire were obtained on completion of each condition.

Results

Objective indexes

The measured results for myoelectric potential were analyzed using the root mean square (RMS) which were used in analysis of the amount of muscular activity. The RMS for 1 action was calculated from the measured results for the extensor digitorum and flexor carpi radialis muscles. This was then normalized by dividing by the maximum muscle activity for each participant, to calculate the average value for each condition.

Analysis was carried out for 11 of the 14 participants for whom there were no measurement errors. The results for myoelectric potential under each condition are shown in Figures 10 and 11. Also, the results for the time required for 1 action are shown in Figure 12.

From multiple comparison of RMS, a significant difference ($p<.01$) was found for the extensor digitorum between Condition 1 and the other conditions, and a marginal significance ($p<.10$) between Condition 3 and Condition 4. On the other hand, no significant difference was found for the flexor carpi radialis muscle.

In the time required for the tasks, it was found that there was a significant extension ($p<.01$) for Condition 2 and Condition 3 where interaction was generated during contact.

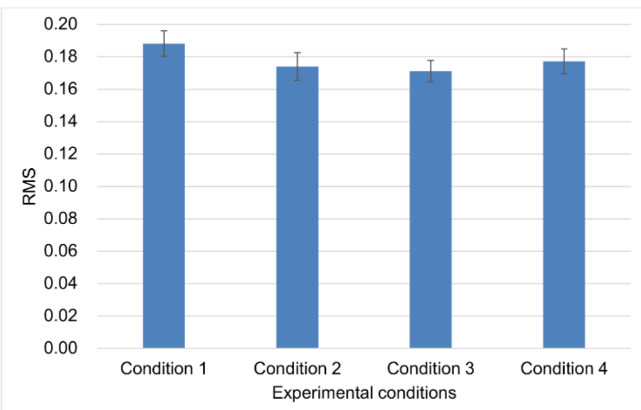

Figure 10. Results for myoelectric potential (extensor digitorum)

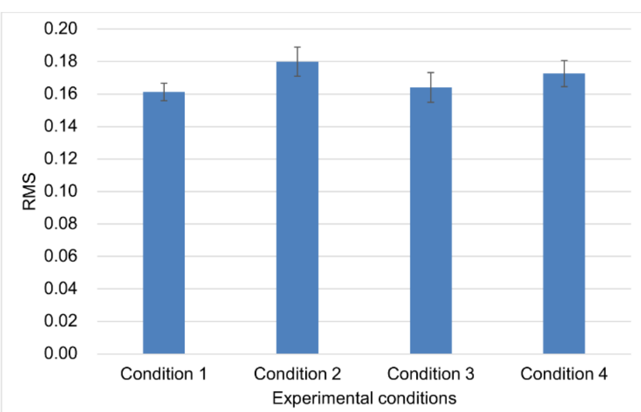

Figure 11. Results for myoelectric potential (flexor carpi radialis muscle)

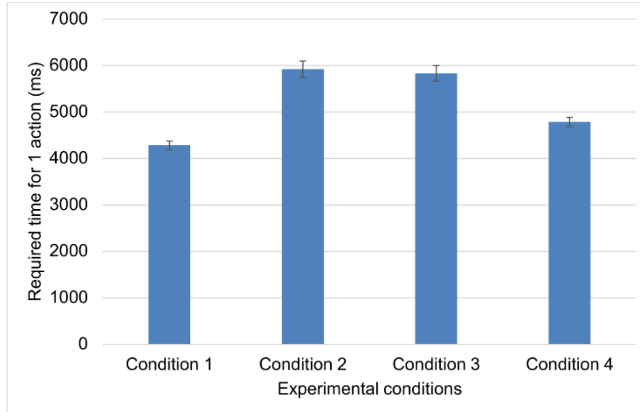

Figure 12. Results for time required for 1 action

Subjective indexes

Figure 13 to 16 shows the mean score for Conditions 2 to 4 for the 4 question items. It was found by multiple comparison that for questions 2 to 4, Condition 2 and Condition 3 were significantly higher than Condition 4 ($p<.01$).

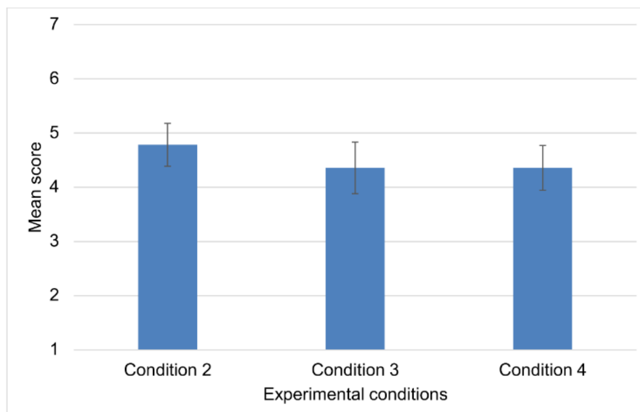

Figure 13. Results for Question 1

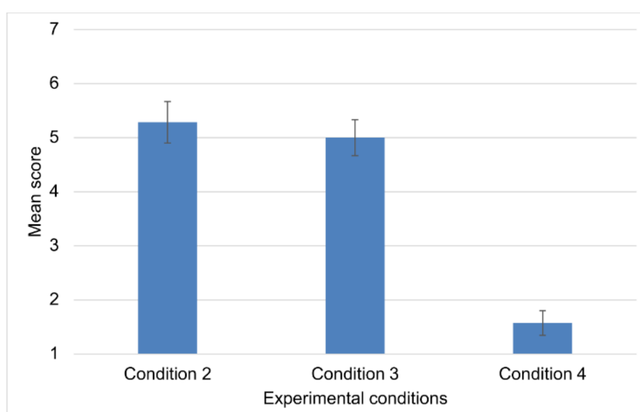

Figure 14. Results for Question 2

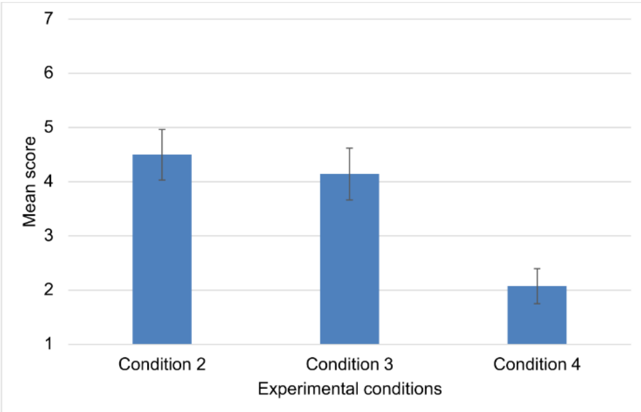

Figure 15. Results for Question 3

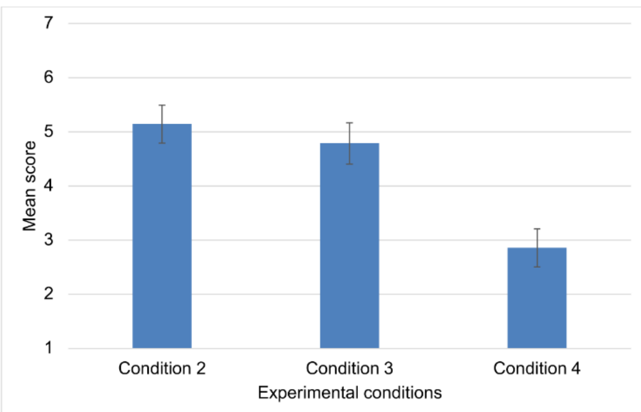

Figure 16. Results for Question 4

Discussion

From the objective indexes it was found that for Condition 2 and Condition 3 in which interaction was generated during contact when the sphere was presented, the amount of muscle activity in the extensor digitorum was marginally reduced, and the time required for the experimental task was significantly extended.

On the other hand, in the subjective indexes, from the scores for the feeling of touch (Question 2), strength of illusion (Question 3), and awareness of body and force (Question 4), it was found that Condition 2 and Condition 3 were significantly higher.

Considering the objective and subjective indexes, it was found that tactile sensation was induced by the 3D images, the motions of the participants were affected, and this was reflected in the muscle output. It is considered that the main factor for this was the interactive representation of the 3D images during contact.

Conclusion

In this research, evaluation was carried out with a pseudo-haptic that induced subtle tactile sensations, focusing on the muscle output of the participants during interaction with 3D images. 3D images were presented using a see-through HMD, and the participants were required to perform the action of pushing it with their palm, during which their myoelectric potentials were measured. When considered together with the subjective indexes, it was found that the muscle output for touching 3D images was reduced and the action time was extended by the increase of the illusion strength.

This tendency was significant under the conditions in which interaction of 3D images was represented. Therefore, it is suggested that as a result of the increase in the feeling of touch and the illusion strength due to interaction during contact, a kind of "cautiousness" may have been added in the action of the participants.

This suggests that the pseudo-haptic in this research could affect the action of touching 3D images. In the future it is intended to conduct the characteristics between the visual representation of the 3D images and the action by the participants in terms of the pseudo-haptic.

References

[1] https://www.microsoft.com/microsoft-hololens/

[2] M. Botvinick, J. Cohen, "Rubber hands 'feel' touch that eyes see," Nature, Vol.391, No.6669, pp.756, 1998.

[3] H. Morikawa et al., "Application of an illusion for tactile interface," Proceedings of the XVth Triennial Congress of the International Ergonomics Association, 2003.

[4] H. Morikawa, et al., "Study of cross modality stimulation for safety-education VR contents," Transactions of the Virtual Reality Society of Japan, Vol.11, No.4, pp.479-485, 2006 (in Japanese).

[5] H. Morikawa and T. Kawai: "Measurement of brain activation using NIRS for evaluation of body image induction by cross-modal stimulation," Journal of Human Interface Society, Vol.10, No.2, pp.191-198, 2008 (in Japanese).

[6] H. Morikawa, et al., "Cross-modal illusion of 'weak' tactile sensation using see-through HMD," Transactions of the Virtual Reality Society of Japan, Vol.18, No.2, pp.150-159, 2013 (in Japanese).

Author Biography

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