

Effect of Self-Action on Hand Tactile Sensing

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Abstract

The ultimate goal of function substitution is to build assistive devices that could be used and felt by the amputee as a part of their own body. Achieving this goal requires motions that are the result of the smooth cooperation of the assistive device and its human user. This in turn requires proper sensory feedback to the controller and to the human being.

Motor-Sensory coordination is one of the basic principles of human and robot motion control. In the case of function substitution, this principle requires the coordination between a human self-action and sensory feedback from assistive devices. Although there are a lot of studies on the effect of sensory feedback in assistive devices, there is little research on how a human self-action could affect the sensory feedback. We believe that a sensory feedback taking the human self-action into consideration might enable the cooperation of the device and its user. In this research, we conducted a series of temporal-order-judge experiment to test self-action's effect on temporal property of hand tactile sensation. Results show that self-action does change the judge accuracy of the temporal-order task. This will bring insights to the realization of a better feedback scheme.

1. Introduction

The ultimate goal of function substitution is to build assistive devices that could be used and felt by the amputee as a part of their own body. Achieving this goal requires motions that are the result of the smooth cooperation of the assistive device and its human user. This in turn requires proper sensory feedback to the controller and to the human being.

Recently, the development of prosthetic hand systems with both decoration and motion functionality for hand amputees has attracted wide research interests. Hand amputees at arm tendon level are now able to achieve some simple movements using a prosthetics device. Still, one of the biggest challenges is how to transmit the sensory information from the prosthesis to the human. Motor-Sensory coordination is one of the basic principles of human and robot motion control. In the case of function substitution, this principle requires the coordination between a human self-action and sensory feedback from assistive devices. Although there are lots of research efforts on the effect of sensory feedback in assistive devices [2], however, there is little research on how a human self-action could affect the sensory feedback. We believe that a sensory feedback taking the human self-action into consideration might enable the cooperation of the device and its user. In [1], a temporal-

order-judge experiment paradigm, in which vibrations with a certain time lag were given to tips of sticks held by subjects, was employed to test the tactile sensing of tools.

In this research, we made use of the experiment paradigm, and investigated whether a self-action could affect the temporal property of hand tactile sensation, thus add a bias to the tactile sensing.

2. Experiment Setting

The subject was asked to sit in front of a table, and hold a straight stick in each hand. 2 small vibrators (4F412: maximum current 10mA, vibration time 50ms) were fixed in the tip of the sticks. A pair of vibration stimulus, with a certain time interval, was given to the tips of the sticks. A small button (Pressure sensor) was set at the lower end of the stick. In this way, the subject was able to use his thumbs to press the buttons. For comparison purposes, the other experimental conditions were set as the same as those in [1]. A total of 28 time intervals ranging from -1500ms to 1500ms (-1500, -900, -600, -400, -300, -200, -150, -100, -80, -60, -40, -30, -20, -10, 10, 20, 30 ... 1500, the sign of the time interval means the sides being stimulated at first), were used in random. The device control and data recording software were implemented in Labview (National Instrument Corp.).

In the first experiment, a series of test similar to those in [1] were conducted for the purposes of comparison. Besides, a self-action session was added, in which, the subject was required to move his/her left fingers to touch the button after hearing a beep. After a 700ms time lag, the vibration stimuli were given to the tips of the sticks. Then the subject was asked to use the buttons to give his/her judgment on which hand was stimulated first. 10 subjects, aged from 20-23, participated in this experiment. For each subject, tests were conducted for each arm cross condition.

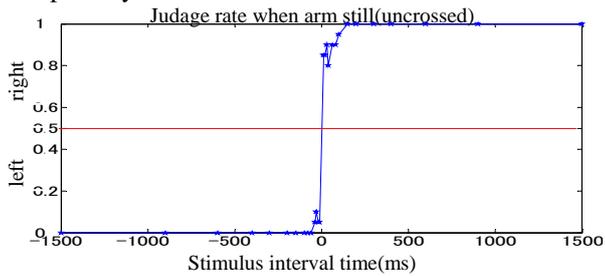
In the second experiment, one of the ten subjects participated in this experiment. The experiment condition is the same as that of self-action session in experiment 1, but the time lag was set to 200ms and 500ms. Tests were conducted to the subject.

3. Results and Discussion

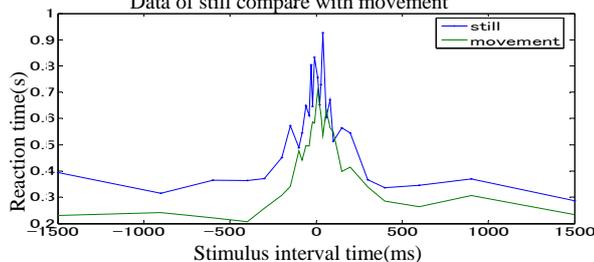
Fig. 1 shows the results of experiment 1. Fig. 1 A) shows the judge rate, and Fig. 1 B) shows the reaction time in the case of uncrossed arm condition. The horizontal axis of these graphs stands for the different time intervals. Fig. 1 C) and D) are judge rate and reaction time graphs for crossed arm condition, respectively. These results basically agree with those

results in [1]. It is apparent that, the smaller time intervals resulted in higher miss-judge rates and longer reaction time. In the arm-uncross condition, it can be noticed that the subject's reaction times are faster when the hand performed a pre-action. Additionally, the detection accuracy of the dynamical left hand was better than the static right hand. In the arm-cross condition, it can be noticed that when the stimulus interval was less than 100ms, the reaction time of pre-acted left side was higher than that of the static side (right hand) (Fig. 2D). But when the stimulus interval was longer than 100ms, the reaction time of the pre-acted side was comparatively short.

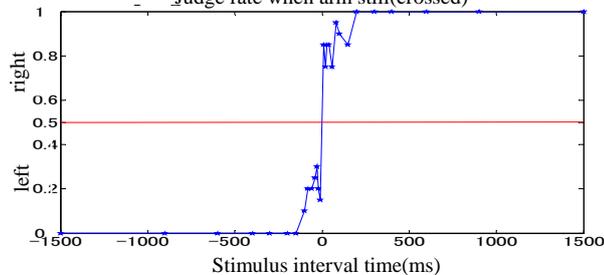
Fig. 2 shows the results of experiment 2. Fig. 2 A) shows the average of reaction time for 10 times. The green line shows the case of 200ms time lag, the red line shows the case of 500ms time lag, while, the blue line shows the case without a pre-action. As shown in the fig. 2 A), a self-action with 200ms time lag made the judgment lower, whereas, a self-action with 500ms time lag improved the reaction time. Fig. 2 B) shows the variance of 200ms and 500ms pre-action cases. The point stands for that of the 200ms case, and the block triangle shows that of the 500ms case. The variance of 200 case was much higher than that of 500ms case, especially when the time intervals were smaller.



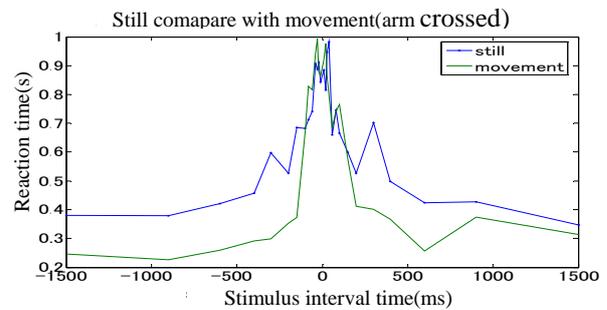
A) The judge rate (arm uncrossed)
Data of still compare with movement



B) The comparer of reaction time (arm uncrossed)
Judge rate when arm still (crossed)

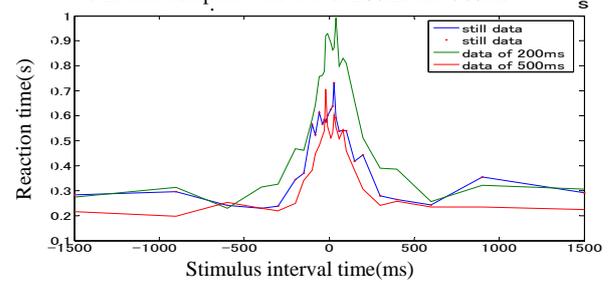


C) The judge rate (arm crossed)

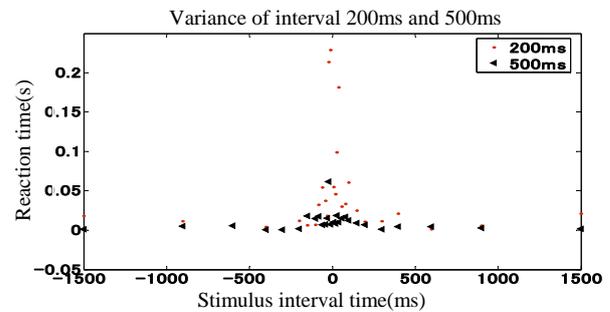


D) The comparer of reaction time

Figure 1 the results of experiment 1
still data compare with data of 200ms and 500ms



A) The average of reaction time (arm crossed)



B) The variance of 200ms and 500ms pre-action cases

Figure 2 the results of experiment 2

Through these preliminary results, we found that, a self action indeed changes the temporal property of tactile sensation. The changes might depend on the time delay between self-actions and sensory stimuli. That might be resulted from the information processing loop relative to the re-fferance principle.

4. Conclusion

Through above preliminary experiments, we found that self-action does change the judge accuracy of the temporal-order task. This will bring insights to the realization of a better feedback scheme. In the future, the trends we found should be reaffirmed by more experiment data.

References

- [1] S. Yamamoto, S. Moizumi and S. Kitazawa, Referral of Tactile sensation to the tips of L-shaped sticks, *JNeurophysiol*93:2856-2863, 2005.
- [2] M. Botvinick, J. Cohen, Rubber hands “feel” touch that eyes see, *Nature*, 391:756, 1998.

Acknowledgement

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