Preliminary Results of a Recognition Training for Dynamical Electrical Pattern Feedback

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Abstract

The aim of this study is to investigate the learning process of dynamical electrotactile perception without visual feedback. We expected that with the aid of auditory information, the learning process could improve the ability to distinguish and remember electrical stimulation patterns with small difference. A finger proprioceptive sensing was emulated and 2 different training methods were used to learn the electrical patterns for the movement. The results show an improvement in the detection of both the movement and position of the finger without visual feedback and the perception becomes more precise after training with audio tones aid.

1. Introduction

Sensory feedback has been proven of great importance to achieve a “close loop” control of a limb. In many relative studies, electrocutaneous stimulation has been used to achieve a sensory feedback [1], but the control and learning were realized with aid of the vision. This study aims for the dynamical feedback for a prosthetic hand; hence achieve a real time limb control with less consciousness awareness. To accomplish the recognition of spatial location of the hand or fingers without visual feedback, we used different training methods. Since the auditory information is processed more rapidly as it does not encounter the long delays of visual channels [2]. For this reason, an audio-tone aided training was conducted. Also, how the learning process affects the detection and retention of small differences in the stimulation was explored.

2. Method

For this experiment 10 subjects between 20 and 23 years old, no distinction on gender, and with no apparent sensory or motor impairment were tested. The subjects were divided into 2 groups: one with audio training, the other with verbal training. For each subject 3 training sessions were held, and the time between each session was approximately a week and a half.

For simplicity purposes, the movement of only one finger was used. The finger motion was divided into 5 positions that correspond to different electrical patterns. Position 1 is when the finger is straight, and position 5 is when the finger is totally bent (Fig. 1).

A bending sensor (Abrams Gentile Entertainment) was used to capture the angle of the experimenter's finger. This information was processed with an H8 3664F microcontroller to generate different stimulation patterns and different tones for each finger position, this way the subject could predict the experimenter’s finger location.

The stimulation consists of 35Hz bursts, with a carrier of 2 kHz, and a variant duty rate. Two modalities of training were used. One is with electrical and verbal explanation; the experimenter told the finger’s position to the subject being stimulated, in this way the latter can adapt to the sensation. The other modality consists in the electrical and audio feedback. In this case the subject heard a tone to guide each position of the finger, and must associate it to the electrical pattern. During the experiment, the idea and expectations were explained to the subject. At this stage a short stimulation was sent to the subject to observe his/her reaction. Because of skin impedance variation between people, for some subjects, the electrical patterns can reach the pain receptors in the skin, creating discomfort. If any unpleasant feeling occurred, the experiment was stopped.

In the next step the subject’s eyes were covered and the electrical stimulation was presented. The subject was asked if he felt any changes in the electrical stimulation while the experimenter’s finger was moving. Only if they could feel at least 2 differences...
from the stimulation, the patterns were judged to be suitable to make the experiment.

The stimulation patterns were presented while experimenter’s indicating the finger position. The sequence 1 to 5 - 5 to 1 was performed 3 times slowly, to enable association between the finger position and the stimulation patterns.

During the test, only the electrical stimulation was used. The actual initial finger position of the experimenter was indicated, then the finger was moved and the subject had to report which position he/she thought the finger was. The finger could be moved one or more positions toward 1 or 5, no move case is also allowed. This was done 10 times.

The second part of the test consisted on trying to recognize the direction of the finger movement, this is up (5 to 1) or down (1 to 5). The experimenter told the subject that he was going to move the finger, and then the movement was done. The subject was asked to report which direction he thought the finger was moved. This was done 5 times.

After the test, the subject could rest for about 2 minutes and was asked to report about the sensations. 2 training periods of about 4 minutes with a rest of 2 minutes approximately between each session was done. In the case of training with audio, a 2 minutes audio training without electrical stimulation was done before the actual training. And in the stimulation training, a cue was given for the first audio tone, then the subject had to repeat loudly the position of the finger according to the tone, and tried to learn the electrical sensation. If the subject made a mistake with the tone, another cue was given.

A 2 minutes rest was taken before the last test. This was the same as the first test, with the same fixed positions. The subject's opinion of the sensations was recorded.

3. Result and Discussion

Although these are preliminary results, we can see that learning to differentiate the electrical patterns improve with continuous training. Fig.1 and fig.2 show the results of the first test that was held on each session (before the training period). There is a tendency to improve towards the same point (2 to 3 mistakes) for the audio aided training subjects. On the other hand, the tendency for verbal training improves more randomly. This indicates that the training with audio tone aid helps to learn the different sensations more accurately than the verbal training. The results of the test after the training in each session have the same tendency. If the electrode area was altered between sessions, or if the subject's hand position was changed, the electrical sensation was modified too. This was a problem for the subject to recognize the exact position, but all of them could approximate the feelings. This suggests that the finger position related perception of the stimulation could be generalized to the small changes. To recognize the finger direction was easier for all the subjects, they all had almost perfect score in recognizing the direction.

4. Conclusion

Throughout the training, the subjects improved the detection of both the movement and position of the finger without visual feedback. It seems that the training with audio tones helps the person to interiorize the electrical sensation, thus getting better accuracy in the learning. The perception of the stimulation becomes more precise after training and can adapt to small changes, therefore the detection of complex patterns may be achieved.

References