THE EFFECT OF VISUAL BIOFEEDBACK FORMS OF MYOELECTRIC SIGNAL ON MYOELECTRIC SIGNAL SEPARATION TRAINING

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INTRODUCTION

Myoelectric control of powered upper limb prosthesis enables the user to control the timing and amount of joint movement of the prosthetic component\(^1\). However, the lack of tactile sensory feedback in the control loop causes difficulties in fine control of the prosthetic component\(^2\). With the natural learning ability, the amputee can form a predictive control, or acquire a control method on incidental feedback during the practical use of the prosthesis. Therefore, an amputee willing to use any kind of myoelectric controlled prosthesis is strongly recommended to spend time to practice with the system to achieve the intended task. It is, therefore, important to enhance the learning processes of embodying the donned prosthesis. Nevertheless, the user of a myoelectric control system is fundamentally required to voluntarily alter the myoelectric signal. It is important to conduct research on the learning process of myoelectric control and the evaluation and feeding back method for the trainer and trainee. In this paper, a quantitative evaluation method for scaling the degree of separation of the myoelectric signals is presented and an experimental system for myoelectric signal isolation training is developed to test the effect of four types of visualization methods.

EXPERIMENTAL SYSTEM

A Personal computer based myoelectric tester is developed for visualizing the myoelectric signal or the detected movement from the signal, as in a commercially available system and previous researches\(^3,4\). The target of this research was focused on the phase of myoelectric assessment and early stage of myoelectric signal control training. In this phase, the target of evaluation and training is improving the independent control and relaxation of flexion and extension muscle to reduce the co-contraction. Therefore, the main function of the software is to visualize the waverin myoelectric signal in realtime for self modulation.

Four types of graphical forms were prepared for the experiment. The forms were selected from the commercially available system, waveform, bar graph, and animation of the computer graphic, CG, hand. In addition, planar distribution graph of the 2-site myoelectric signals, which is used in describing the relation of activity level of the ‘operating points’ in the proportional control\(^1\), is also prepared. The forms’ screen shots are shown in Figure 1.

The experimental system consists of 2 sets of myoelectric sensors (Otto Bock, MyoBock 13E200=60) and a personal computer with an AD converter board (Interface, PCI-3168). The sampling frequency is set to 1 kHz. The raw data sampled from the sensor signal is concurrently recorded. In the CG form, two-site two-function On/Off control strategy under first-come-first-served condition is used to control the hand opening/closing.

The tester was designed with two modes, practice and evaluation. In the practice mode, one out of the 4 types of screen is shown on the 22-inch LCD. Targeted level band, which the subject tries to hold the signal within, is shown in diluted color. The target band are shown, ‘On,’ for 2-seconds and ‘Off’ 3-seconds in series, while the sites and the levels, high and low, are switched consecutively. The On/Off is repeated 20 times for one set of trial, and 5 sets of trial is carried out with intervals in between. For the CG form, the target finger positions are shown in blue. Once the operating finger is located within the allowable displacement and maintained for 3-seconds, the next target position is shown. This is repeated 20 times as one set of trial. As for the evaluation mode, the CG form is shown and 5 sets of the above mentioned routine is carried out.

Figure 1: Forms for the practice and evaluation modes. From top left, waveform, bar, planner distribution, and CG.

EXPERIMENT

The experiment was approved by the university IRB and all subjects participated in the experiment after
providing a written informed consent. 20 non-amputated adult males (Mean: 23.2 year-of-age) participated. The myoelectric sensors were placed on the surface of their non-dominant forearm. The initial positions of the sensors were selected after palpation and confirming the muscle contraction. The sensors were attached to the skin with adhesive tape and an elastic strap was wrapped over the sensor. Subjects sat on a chair in front of the monitor and the tested arm was held at elbow flexion 90 degrees during the practice. All subjects participated only once in a 5-day program: consisting of 5-sets of pre-practice evaluation, 5-sets of practice and 5-sets of post-practice evaluation, each day. Five subjects, randomly selected, took part in the forms, respectively. The subject’s wrist joint were braced with a plastic cast and fixed to a posture of the thumb positioned upward.

To quantitatively evaluate the quality of the isolation during the voluntary muscle contraction, the next equation is applied. The degree of isolation $D_t$ is calculated from the flexor myoelectric signal $V_{Ft}$ and extensor myoelectric signal $V_{Et}$ sampled at time $t$. Since the signal isolation is important at activation, the period which one of the signals exceeded the threshold of 0.2 Maximum Voluntary Contraction is selected from the recorded myoelectric signals and computed. This threshold is also used in the CG movement discrimination algorithm.

$$D_t = \frac{|V_{Ft} - V_{Et}|}{V_{Ft} + V_{Et}} \quad (V_{Ft} \neq V_{Et} \neq 0) \quad (1)$$

**RESULT**

The average degree of isolation computed for each subject for the pre-practice evaluation of the first day and the post-practice evaluation of the last day is shown in Figure 2. Nineteen subjects, out of 20, had higher isolation at the end of their training period. Multiple-comparison, Bonferroni t-test, was conducted to analyze the influence of the visual forms used in the practice. The subject’s last day’s post-practice evaluation result was tested. As described in Table 1, the result showed no significant differences between the groups.

**DISCUSSION**

With the variety of subject’s evaluation results show that the degree of isolation has good sensibility as a scale to detect the changes of individual’s performance.

The statistical analysis results show that the screen setting and the properties of visual information fed back to the subjects were not the major factors for varying the degree of isolation. No pair of comparison showed notable difference and this was confirmed to be equivalent for the evaluation results of the pre-practice result of the first day. From these result, it can be assumed that the practice can be planned on any form. Finally, caution is necessary since the results are extracted from a limited subject population. All subjects in this experiment major in engineering and are keen of graphical representation of collected data. The planner distribution form may be difficult to appreciate in some amputee, and further testing is essential.

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**REFERENCES**

