HOW IS AUDITORY EMG BIOFEEDBACK EFFECTIVE FOR BLIND PEOPLE?

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ABSTRACT

In this study, 11 sighted and 10 blind subjects performed a motor task requiring 20 muscle contractions at a pre-determined target (20% maximal voluntary contraction, MVC) with or without auditory EMG biofeedback (AEB) to examine whether the AEB-induced changes in motor performance differ between groups. The AEB reduced the absolute difference from one previous contraction only in the blind subjects (-34% on average; $p = 0.026$), and the error with no biofeedback was greater for the blind subjects compared to that for the sighted subjects (5.20% MVC SD (2.05) and 3.30% MVC SD (1.26); $p = 0.024$). This was consistent with subjective rating data showing a trend that the blind subjects felt performing the task with no biofeedback more difficult than did the sighted subjects ($p = 0.06$). These data suggest that poor motor performance of blind people can be improved with AEB.

1. INTRODUCTION

Seeing or hearing information converted from internal biological signals (biofeedback) can improve motor performance [1]. The amplitude of electromyography (EMG) reflects how active the specific muscle is working, and therefore, it has been reported that EMG biofeedback has a beneficial effect in motor control in various circumstances [1, 2].

Visual image is most commonly used for EMG biofeedback [3-5]. However, sound generated from EMG signal has been shown to provide as much information as visual image when performing a certain motor task [6-8]. Although use of sound has the advantage for anyone because one can move more freely without staring at a display, for blind individuals who have to depend on non-visual information, sound would be the first choice when EMG biofeedback is conducted.

It has been shown that blind individuals can successfully learn facial expression with use of auditory EMG biofeedback (AEB) of facial muscles [9, 10]. Therefore, it seems obvious that AEB is applicable to blind individuals. However, how blind individuals respond to AEB when directly compared to sighted individuals is not known. Because blind individuals have been shown to compensate for their visual deprive by sharpening auditory processes [11], they may behave differently to AEB when compared to sighted individuals. Moreover, there are some studies showing that blind individuals do not perform motor tasks as well as sighted individuals [12-16], and therefore whether poor motor performance could be compensated by the sharpened auditory process in the blind is an interesting question. If so, more active use of AEB is suggested when precise, repetitive motions are required such as in rehabilitation or sporting activities.

The purpose of this study was to determine whether AEB-induced changes in motor performance differ between blind and sighted people. We hypothesized that AEB would improve motor performance in both sighted and blind individuals, but blind individuals would benefit more from AEB than sighted individuals.

2. MATERIALS AND METHODS

2.1. Subjects and general design

A total of 21 (10 blind and 11 sighted) subjects were recruited. There were two females in each group, and their mean age was 22.9 years with no between-group difference. The blindness was congenital for 6 subjects, and the rest (4 subjects) acquired blindness at the age of 12 to 21. All subjects gave written informed consent to the study, which was approved by the internal review board at Tsukuba University of Technology.

The subjects were asked to perform a same motor task of gripping a dynamometer repetitively at 20% of their maximum voluntary contraction (MVC), under three different biofeedback conditions: Auditory EMG biofeedback (AEB), Visual EMG biofeedback (VEB), and No Biofeedback.

2.2. Experimental set-up and instrumentation

In this study, sitting subjects placed their fully supinated forearm on a table in front of them, and were asked to grip a dynamometer (T.K.K. 5401, Takei) with their dominant hand. Each task consisted of 20 contractions, and each contraction was held for 5 seconds at 20% MVC with 10-second rest between (Figure 1).

Prior to performing each motor task described above, the subjects practiced enough, so that they were able to contract the muscle at the target 20% MVC easily. During the practice, verbal cues were about the level of contraction, such as “more” or “less”, but once the task started, the verbal cues were regarding timing only such as “3, 2, 1, go” and “relax”. The subjects performed the practice and motor task under the same feedback condition (e.g., practice with no biofeedback and then perform the task with no biofeedback).

Surface EMG was collected by placing two electrodes on the flexor digitorum superficialis and a ground electrode on the dorsum of the tested hand. The signal was amplified (x500, EMG-025, Harada Electronic Industry Ltd) and digitized (1kHz, USB-6216, National Instruments).

AEB and VEB were achieved with MATLAB (R2012a, Mathworks). For AEB, two speakers (6010A, Genelec Oy) were placed on the table in front of each ear of the sitting subject. We assigned parameter mapping sonification [17] for synthesizing sounds. A sinusoid (frequency = 460Hz) was generated, and its amplitude reflected the EMG amplitude continuously. The study was done in a quiet research laboratory (48dB), and the loudness of the sound was adjusted to be 58dB, 65dB, and 72dB when the EMG amplitude was at 20%, 50% and 100% MVC, respectively. For VEB, a bar appeared on a display placed in front of the sighted subject, and its height reflected the EMG amplitude. No sound was used during VEB.

Subjective ratings were obtained by asking how easy it was to perform the task. The ratings ranged from 1 (“very difficult”) to 5 (“very easy”) with 3 being “ordinary”.

2.3. Experimental procedure

Upon arrival to the laboratory, electrodes were placed and MVC was measured for EMG normalization purpose. Then subjects practiced and performed the task described above. The subjective ratings were collected after the 2 sessions (AEB and no biofeedback sessions), and the VEB session was conducted for the sighted subjects. After the 20th contraction in each task, MVC was taken in order to make sure no fatigue was induced by the task. A 10-minute rest was given between sessions in order to prevent fatigue.

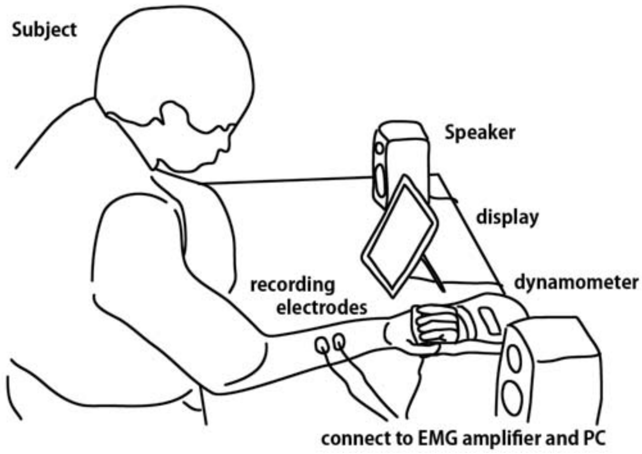

Figure 1: An Experimental set-up and instrumentation. Sitting subjects placed their fully supinated forearm on a table in front of them, and were asked to grip a dynamometer.

2.4. Data reduction and analysis

EMG amplitude was calculated from the last 2 seconds of 5-sec contractions, and normalized to MVC.

In order to examine the motor performance, error was calculated as the absolute difference from one previous contraction. This error index represents the effect of the biofeedback on a shorter term motor and auditory memory, compared, for example, to the absolute error against the task target (20%MVC) which requires the memory of the reference given at the beginning. Memory capacity may differ among the individuals and may make evaluation more complex.

Two-way (“ group ” x “ biofeedback ”) analysis of variance (ANOVA) was used with the alpha level of 0.05.

3. RESULTS

3.1. Effect of practice and fatigability

The 1st of the 20 contractions in the task was close to the target 20% MV C, and there were no interaction or main effects of “group” or “biofeedback” (the means ranging from 20.9%MVC for the sighted with the AEB to 23.2%MVC for the blind with no biofeedback).

Pre-task grip force was similar between groups (21.5kg SD (6.4) and 26.3kg SD (5.7) for the blind and sighted subjects, respectively; $p = 0.10$). The post-task MVC grip force did not show any change from pre-task, and similar results were found for the post-task MVC EMG amplitude. These results indicate that no fatigue was induced with the low target contraction (20%MVC) and the long between-contraction rest (10 sec off and 5 sec on).

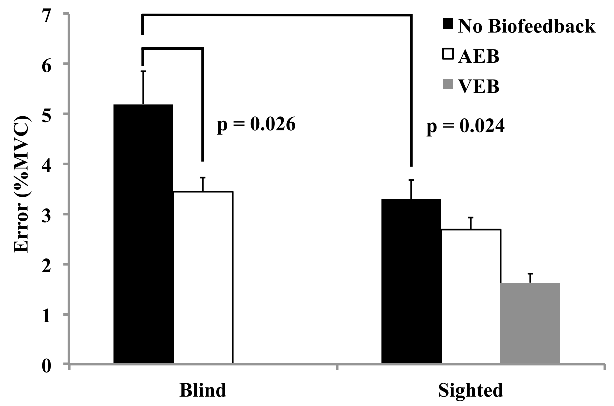

Figure 2: Error from one previous contraction. The auditory EMG biofeedback (AEB) reduced the error only in the blind, and the motor performance with no biofeedback was poorer for the blind subjects than the sighted subjects. The error bars are standard error.

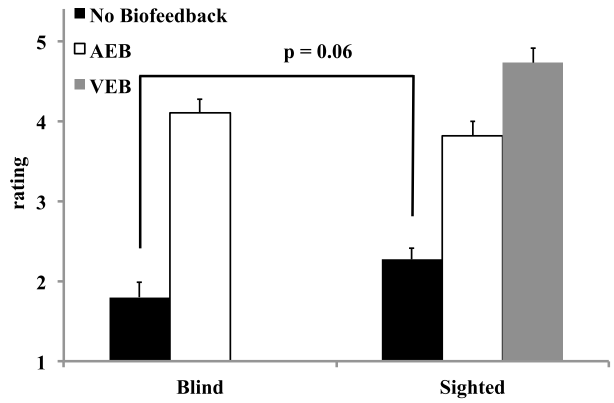

Figure 3: Subjective rating. The blind subjects had a trend to feel that it was harder to perform the task with no biofeedback than did the sighted subjects. The smaller the number, the harder the subjects felt (1 being very difficult, 5 being very easy)

3.2. Motor performance

The error was reduced only in the blind subjects (3.45%MVC SD (0.88) and 5.20%MVC SD (2.05); p = 0.026; Figure 2). Moreover, the error with no biofeedback was greater for the blind subjects than that for the sighted subjects (p = 0.024).

3.3. Subjective ratings

When the subjects were asked to rate how easy it was to perform the task (to reach and maintain the target contraction) for each condition, the overall averages were 2.05 (2 being hard) and 3.95 (4 being easy) for no biofeedback and the AEB, respectively (Figure 3). There was no between-group difference, but the blind subjects tended to feel that performing the task with no biofeedback was harder than did the sighted (3 out of 10 blind subjects rated 1 (very difficult), whereas none of the 11 sighted subjects did; p = 0.06).

4. DISCUSSION

The main findings of this study were that blind people felt it was harder to repetitively contract muscles at a pre-determined level than did the sighted people when there was no biofeedback available, and the motor performance in this kind of task was actually poorer than that of the sighted people. However, auditory EMG biofeedback significantly reduced the error of the blind people, which was not the case for the sighted people. The original hypothesis was that the AEB would reduce the error in both blind and sighted people, but the AEB-induced reduction in the error would be greater for the blind people because it has been reported that blind people compensate for their visual impairment by sharpening auditory process [11]. Our hypothesis has been partially supported (Figure 2). It has been shown that AEB could provide as much information as visual image [8], but in this study, the AEB did not change the error in the sighted people. This is probably due to the task being too simple (holding 20%MVC for 5 sec), and therefore a floor effect may have played a significant role in the sighted people.

When no biofeedback was provided, both blind and sighted subjects were in the same condition where they had to rely on their somatosensory system. It has been shown that visual cortical area can be activated by somatosensory input in blind subjects, but not those with sight [18-20]. One may predict that blind people would benefit more from somatosensory system than sighted people, but this was not the case in this study. This may be due to the fact that the task was unusual, novel one (griping a dynamometer with forearm supinated and elbow flexed).

Modifying the sonification design could increase the effectiveness of biofeedback. The sonification method employed in the present study varied the loudness corresponding to the muscle activity. Loudness is quite easy to manipulate and is familiar to users. However, there were several drawbacks to using loudness for continuous data sets in sonification; lack of resolution, and memorability. Neuhoff stated that absolute data values are particularly difficult to perceive by listening to loudness change alone [21]. In this rehabilitation task, one possible solution is that sensitivity to rhythm can be exploited to indicate processes. For example, Wallis' study showed changing in rhythm and tempo is fruitful for stroke rehabilitation [22].

Feedback and practice are considered to be among the most important variables in the process of motor learning [23]. Our data suggest that AEB is a powerful biofeedback tool that can be used in rehabilitation and sporting activities for blind people. Further studies are necessary in order to investigate what kind of motor task / AEB would lead to the best motor performance in blind, as well as in sighted people.

5. CONCLUSION

In this paper, we have examined whether the auditory EMG biofeedback induced changes in motor performance differ between sighted and blind groups. The experimental results showed that the AEB reduced the absolute difference only in the blind subjects. In addition, subjective rating data revealed that the blind subjects felt performing a motor task with no biofeedback was more difficult than did sighted subjects. Our experimental data indicate that the AEB is as effective as, or probably even more effective for blind people than for sighted people, and therefore the more active use of AEB should be considered in various activities for blind people.

6. REFERENCES

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