Effect of EEG-based Neurofeedback Training on Improving Speech and Limb Motor Reaction Time

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INTRODUCTION

Background:
Neurofeedback training is a promising new technology for the therapeutic treatment of various neurological conditions, including Parkinson's Disease, Attention-Deficit/Hyperactivity Disorder, epilepsy, and tinnitus **[2, 3]**. However, there is limited data regarding its efficacy as a method of movement rehabilitation.

While neurofeedback training can target a variety of neuronal oscillation frequencies, this study focused on beta band activity (13-25 Hz), in which desynchronization occurs before and after cued motions **[1]**. Given this information, we would hope to see an overall decrease in beta band power from the motor reaction task before neurofeedback to the motor reaction task after neurofeedback. Data regarding neurofeedback has not been strongly conclusive yet, as failures could be attributed to individual characteristics of subjects. Thus, more support for the effects of neurofeedback, as well as a greater understanding of the associated neural correlates, will improve our understanding of its therapeutic potential **[4]**.

Objective:
This study examined the effect of EEG-based neurofeedback of the beta band activity on motor reaction time in simple speech and limb motor tasks.

Questions:
1 – Can neurofeedback training enhance motor performance during and after a motor imagery task?

2 – What characteristics of the subject's EEG data are affected by neurofeedback training?

METHODS

Participants: 30 right-handed, neurotypical subjects were recruited from the 18-25 year old age range. 10 females and 5 males participated in each condition. Participants were randomly assigned to either the a) neurofeedback experimental group or the b) control group.

Data acquisition: To probe the measure of brain activity, electro-encephalography (EEG) signals were simultaneously recorded from 64 scalp electrodes following a standard 10-10 montage during randomized voice and button press motor reaction time tasks. The experimental paradigm is shown in Figure 1 below.

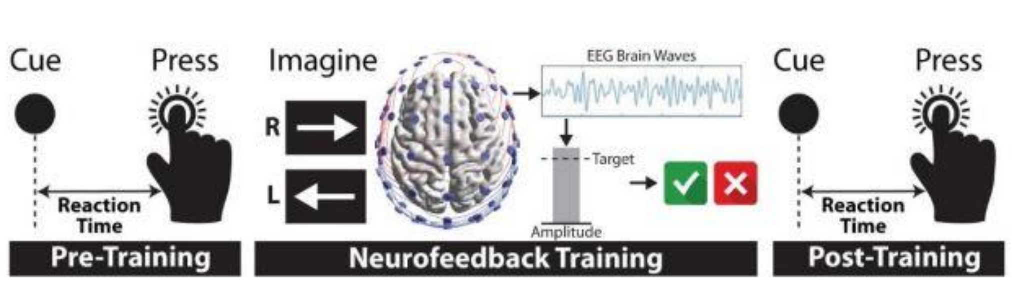

Figure 1. Experimental paradigm: Pre and post-training measured reaction time by simple button-press and speech-onset tasks. Experimental groups did neurofeedback training while control groups participated in an extended resting state. After pre-training, resting state brain activity was analyzed for 7.5 minutes in both groups.

RESULTS

Motor Reaction Task:
The motor reaction task required subjects to respond to either a button press or vocal cue. During the button press task, a small circle in the corner of the screen would appear to cue the subject to press the button, and would disappear to cue the subject to release. Similarly, the vocal task was guided by a small circle, which would cue for the vocal onset and offset. The reaction time of each individual to the cues were recorded for the behavioral analysis.

Neurofeedback Task:
During the neurofeedback training task, the experimental group viewed a real-time display of beta band activity, presented in the form of a bar. The participants were instructed to attempt to lower the bar using mental processes, but without physical movement. Neurofeedback training lasted for a total of 15 minutes. During this time, the control group participated in a measure of their resting brain activity,

Data Analysis – Behavioral Data:

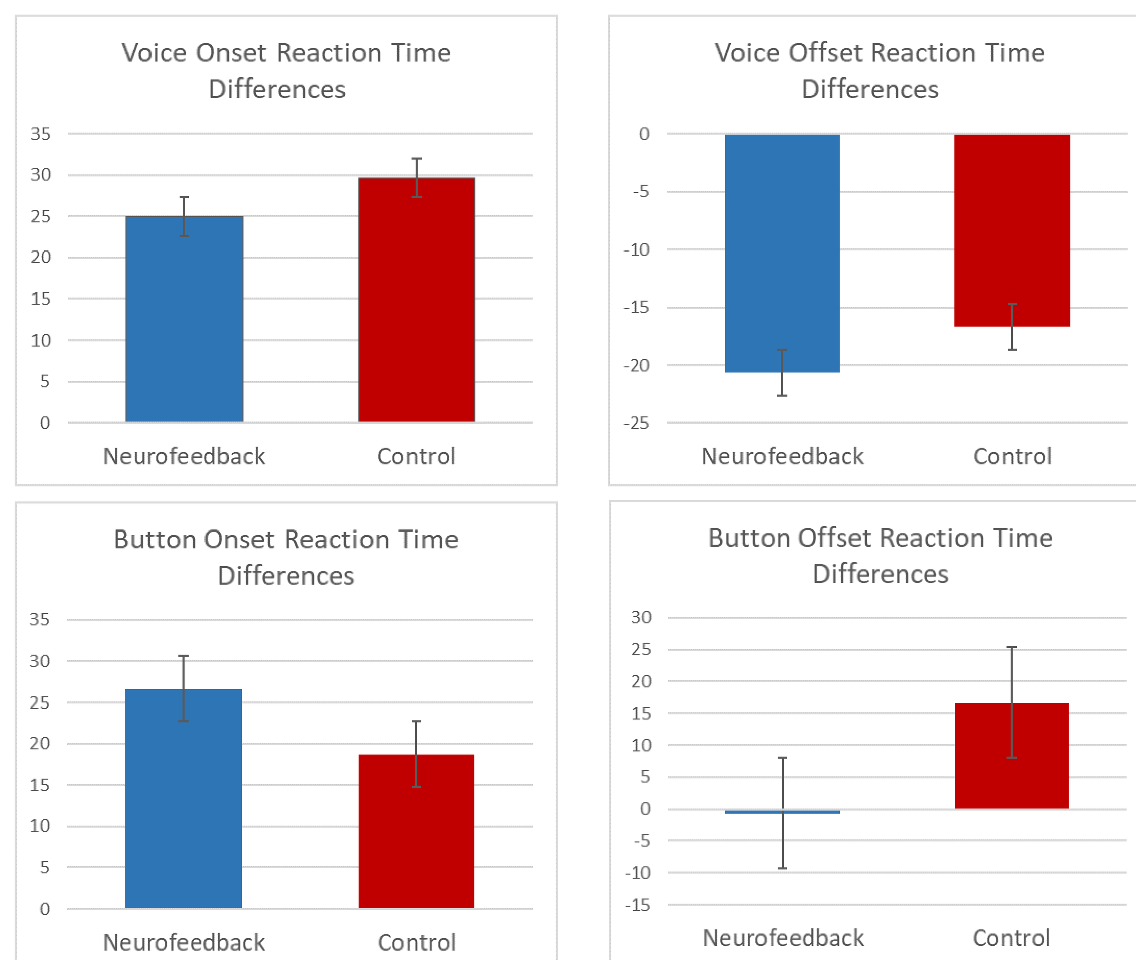

Figure 2. The average reaction time difference (measured in milliseconds) for the neurofeedback and control groups for each condition. A negative result indicates a reaction time that has reduced from the pre-training reaction time task to the post-training reaction time task. Positive results indicate that the reaction time has increased from the pre-training task to the post-training task.

Data Analysis – EEG Data:
Differences in beta band power Z-scores from pre-training trials to neurofeedback training trials were calculated. by averaging the pitch frequency contours (in cents) across all trials. The individual pitch contours were averaged across all subjects to obtain the grand-average profile of the speech compensation responses for the aphasia and control groups.

Data Analysis – Correlation:
The correlation between the difference in stimulus reaction times (before and after neurofeedback) and EEG beta band power differences (before and after neurofeedback) were analyzed. The reaction time difference for vocal onset, vocal offset, button press onset, and button press offset were averaged for each subject. The corresponding scatter plot includes the average of this reaction time difference, graphed against the average beta band power Z-score difference for each participant.

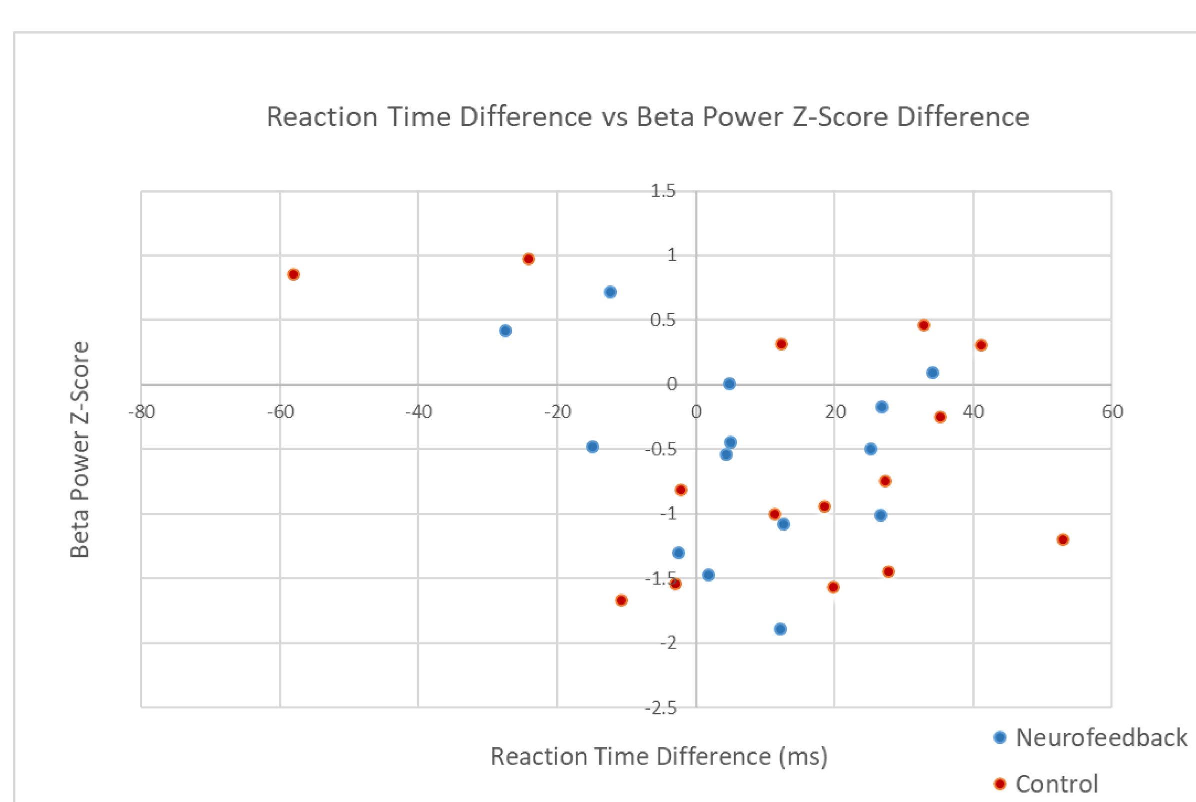

Figure 3. A scatter plot depicting the relationship between average motor reaction time and average beta band Z-score power. The plot is subdivided into neurofeedback training and control groups, with the different colors representing different experimental groups. A loose negative correlation between reaction time difference and beta band power Z-score can be observed. A more pronounced negative correlation can be observed in the neurofeedback group, whereas the control group has a weaker negative trend.

RESULTS (Continued)

t-test Analysis (Behavioral Data):
Differences in reaction time to voice and button press responses in pre-training vs. post-training trials were averaged and then analyzed using paired t-tests.

A statistical analysis of the neurofeedback versus control reaction times revealed a significant difference in average reaction times between the two groups. A two-sample group analysis of the difference in reaction times to the vocal offset cue revealed a p-value of $p = 0.00064$, which is well over the 95% confidence interval to determine the result statistically significant.

t-test Analysis (EEG Data):
Statistical analysis of the EEG data did not reveal a significant between-group difference in the modulation of neural activity beta band power. A two-sample group analysis revealed a p-value of $p = 0.984496$.

DISCUSSION

Our findings suggest that neurofeedback training does not consistently decrease the reaction time in both vocal feedback or physical reaction.
This data exemplifies a decrease in reaction time for the neurofeedback group in the offset of the speech and limb motor tasks. Conversely, there was an increase in reaction time for the onset of the two tasks. For the control group, there was a consistent increase in reaction time for all motions except the voice offset reaction time, which decreased alongside the neurofeedback group. Another piece of data that demonstrates the correlation is the scatterplot containing the average reaction time difference of the individual participants, coupled with their respective beta band powers. There is no obvious difference between the reaction time and corresponding beta band power for the two groups. Both groups appear to have the same number of data points in the negative y-region of the scatter plot.

One conclusion we can make is that neurofeedback training can enhance the reaction time of the offset of the tasks at hand.
This can be shown in the data as the neurofeedback group for the voice offset, as well as for the button offset, showed decreasing reaction times compared to the control group. For the button offset in the motor reaction task, the neurofeedback group average was in the negatives, showing a decrease in reaction time from pre- to post-training, compared to the control group which shows an increase in reaction time.

These findings provide insights into the effectiveness of neurofeedback training for treatment of neurological conditions such as Parkinson's Disease. With future research, we hope to gain a greater understanding of the therapeutic potential of this technology.

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