Enhancement of Cortical Signals to Improve Brain Machine Interface Performance by Inducing Mirror Neuron Network Activation

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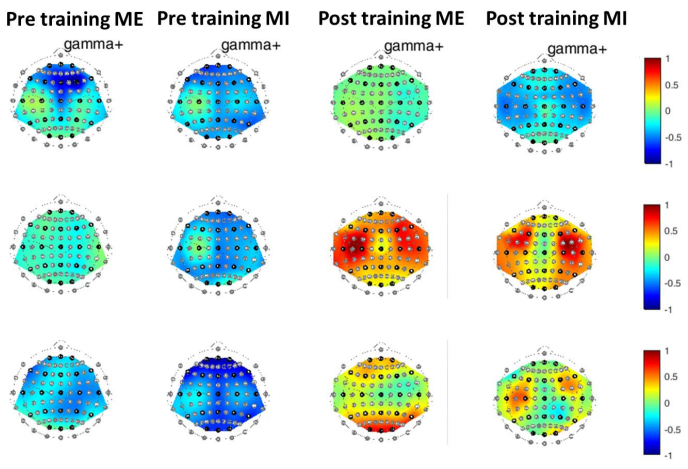
Introduction

Brain Machine Interface (BMI) systems allow patients with neurological injuries to control assistive devices using cortical signals produced during motor imagery (MI). To improve BMI performance, we sought to enhance cortical signals by training subjects in MI techniques that induce activation of mirror neuron networks (MNN).

Methods

Three subjects were trained to perform MI of three tasks by either observing an avatar perform movements in virtual reality (VR) setting, or by watching a video of a researcher performing the tasks (action observation - AO). Baseline MI ability was assessed using a customized scale. Subjects were trained in motor imagery alone, without concomitant motor performance training. Mirror neuron network activation patterns were evaluated in healthy subjects using EEG at baseline, during an MI training session, and after 12 training sessions. Cortical signals were processed using Laplacian spatial filtering across various frequency bands for each of the recording electrodes. Task classification was performed using linear discriminant analysis. Two dimensional head plots were created to display quantification and spatial distribution of neural activation patterns during performance and imagination of the three tasks. Confusion matrices were developed to determine classification accuracies for each task. Noise bursts were pruned from the data and ICA decompositions were run. Artifactual components were rejected in order to control for EMG related activity.

Figure 1

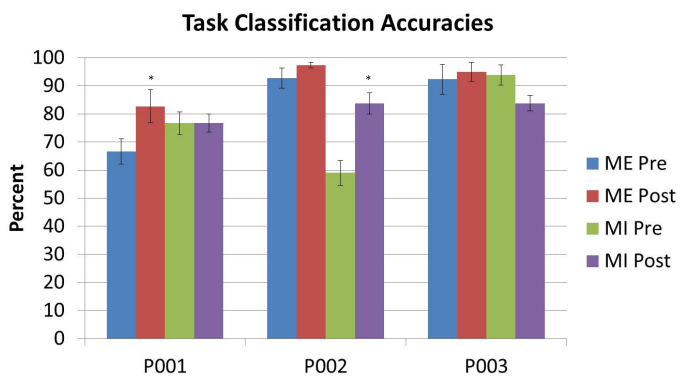


Two-dimensional head plots demonstrating cortical activation patterns in the high gamma band (50-70Hz) during performance of movement (ME) and imagination of movement (MI) for three tasks: drinking from a glass (row one); foot tapping (row two); walking (row three) before and after subject 1 participated in 12 VR based MI training sessions.

Results

Increased cortical activation patterns were spatially located in motor, premotor, and supplementary motor areas and were noted in both contralateral and ipsilateral cortices in both VR subjects and one AO subject, most notably in the alpha and high gamma (50-70Hz) frequency range, consistent with mirror neuron network activity (Figure 1). Task classification accuracies improved across most tasks in all subjects. This effect was more pronounced for motor performance tasks, compared to motor imagery tasks. The greatest increase in classification accuracies was observed in training those tasks with the lowest initial classification (Figure 2).

Figure 2



Average classification accuracies of three distinct tasks during motor imagery or motor performance based on confusion matrices before and after MI training

Conclusions

Motor imagery training enhances cortico-motor signals that may be used to control BMI based neural prosthetic systems. Our results suggest that motor imagery training of tasks with initially low classification accuracies may improve BMI performance.

Learning Objectives

1- Understand the limitations of current BMI systems

2- Identify factors which may improve BMI performance

3- Describe mirror neuron networks and discuss their potential role in BMI operation.