Beta-Band Power vs. Frequency During Movement Fixation and Execution in the Human Hippocampus

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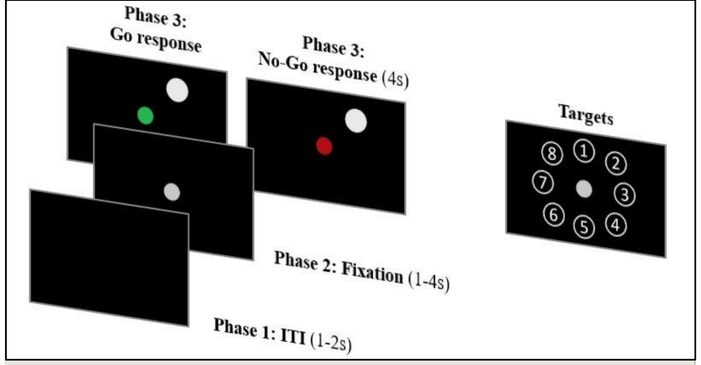
Abstract

The hippocampus, a brain structure situated in the temporal lobe of each cerebral cortex, plays a vital role in long-term memory and memory recovery. It also relates to spatial memory, which helps humans keep track of the locations of objects and the position of their body relative to objects around them. However, the relationship of the hippocampus and the beta-band (13-30 Hz) during movement inhibition and spatial navigation has not been explored as deeply as other frequencies such as the theta band (3-8 Hz), which has been studied using stereotactic electroencephalography (SEEG). In this study, we analyzed anonymized data[1] that was previously collected using SEEG from medically refractory epilepsy patients during the Go/No-Go direct-reach task. The study of the beta-band is significant in understanding its modulation during movement execution and inhibition within the hippocampus. Using MATLAB, a computational programming language used for analyzing and creating systems, we processed and plotted the observed

Objective

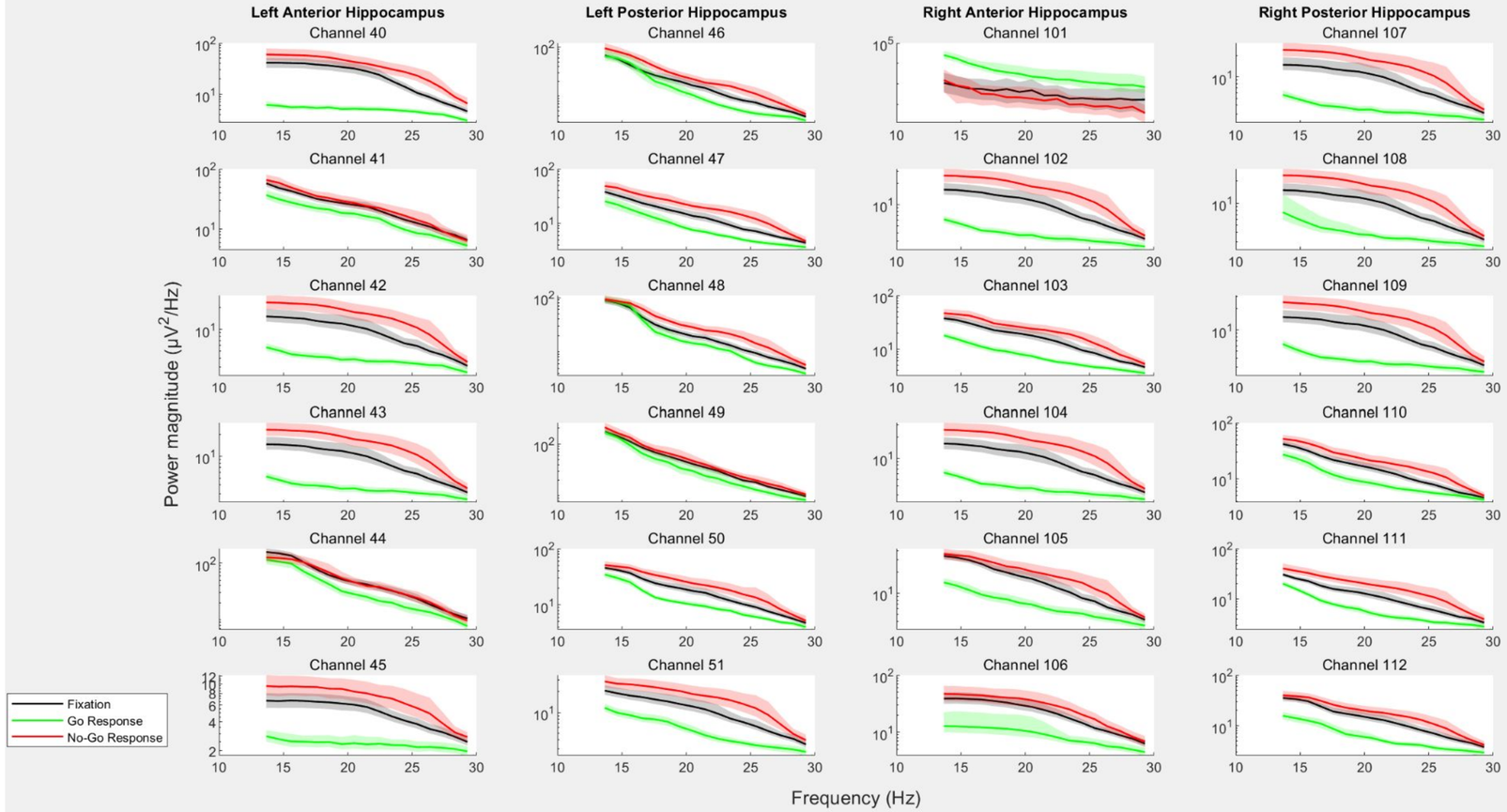
The objective is to analyze the beta-band modulation in the human hippocampus during movement execution and inhibition.

Go/No-Go Task



The Go/No-Go task is a movement-based experiment which was custom programmed on MATLAB© (2018b, The MathWorks, Inc., Natick, MA, USA) and displayed on a 21.5-inch LED-backlit screen with a resolution of 1920 × 1080 pixels and a luminance of 250 cd/m2 (S2240Tb, Dell Inc., Round Rock, TX, USA). The task involves three phases and all trials are conducted consecutively without interruption. The first phase, the Inter-Trial Interval (ITI), is a 1-2 s period with no visuals displayed during which participants have their right arm about 2 inches away from the screen. During the following Fixation phase, a gray dot with a radius of 9.53 mm appears at the center of the screen and participants are instructed to stare and point at the dot without touching the screen. This 1-4 s duration serves as a baseline period for data analysis. In the final Response phase, a white circle with a radius of 15.88 mm appears at one of eight target locations shown in the model above, and simultaneously the fixation dot changes to either green for Go or red for No-Go. In the Go condition, participants double-tap the target circle with their right arm. The time from the target appearance to the tap is recorded as the response time. In the No-Go condition, the participants do not move from their arm position in the fixation phase. The response time for the No-Go is set as 4 s starting at target appearance. Phase durations and trial conditions were pseudo-randomly chosen for each target to be presented eight times, split evenly between Go and No-Go.

Trial-Averaged Power Spectral Density with 95% Confidence Intervals for Fixation, Go, and No-Go Phases



- In the recording of the data, each electrode is tied to a “channel” of data with a value corresponding to the power during each phase at a certain frequency sample. Each column in the graph shows the channels from electrodes implanted in that brain area.
- The graphs show the beta-power on a logarithmic scale y-axis.
- There is a decrease in power from the fixation phase to the go response phase everywhere except in the left hippocampus, where a few channels have a slight decrease from fixation to go.
- Conversely, the no-go response consistently shows an increase in beta-power from fixation.
- These observations show that the beta-band is inhibitory, which means that the beta-band has increased power during movement inhibition and decreased power during movement execution.
- The confidence intervals suggest that there is significant changes when there is no overlap between them, although we have not yet run statistical tests to confirm this.
- Channel 101 shows notable variation from the rest of the channels, with an extremely high power value (up to 10^5 whereas the other channels barely reach above 10^2) and having an increase in power during go and a decrease during no-go. This change is likely due to interference with the signal.

Summary

By creating a spectral density graph and studying it, we noticed a decrease in beta-power within the anterior and posterior hippocampus during movement inhibition and execution. These two functions are important within the human hippocampus, and are displayed during the go/no-go task. During data analysis, the beta-power shows minimal variation. Furthermore, the decrease in power over frequency suggests that lower frequencies have correspond more to inhibition since the difference is less distinguishable in higher frequencies. Overall, the magnitude of the no-go phase was higher than fixation while the go phase was slightly lower. This indicates that the hippocampal beta-band is closer associated to movement inhibition rather than execution. These findings show us that it is possible to use specific channels in the hippocampus to control movement inhibition within prosthetics.

References

1. Del Campo-Vera RM, Tang AM, Gogia AS, Chen KH, Sebastian R, Gilbert ZD, Nune G, Liu CY, Kellis S, Lee B. Neuromodulation in Beta-Band Power Between Movement Execution and Inhibition in the Human Hippocampus. Neuromodulation. 2022 Feb;25(2):232-244. doi: 10.1111/ner.13486. PMID: 35125142; PMCID: PMC8727636.

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