

Investigation of Cortical Activity Responses in Motor Initiation for Release Go/No Go in Hand Exercise Grip Task

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Abstract Parkinson's disease (PD) patients have issues characterized by the degeneration of the basal ganglia and dopamine neurons, which leads to the freezing of gait and slow movement. The mechanism of changing from standing state to walking state in the gait cycle is characterized by the repeated activation to deactivation of specific leg muscles. The purpose of this study is to investigate this brain activity of muscle deactivation, and compare it with muscle activation to determine the cortical mechanism involved in muscle release. We compare a Normal Go/ No Go trial which involves activating a muscle, and Release Go / No Go, which involves deactivating a muscle via measuring EEG and EMG response when using an exercise grip in response to a stimulus. Our results show a higher change in Event Related Spectral Power (ERSP), specifically as Event Related Desynchronization (ERD), during a Release No/Go. We also observe that a Release Go produces a significant ERD response in the Gamma Band. This indicates that the decision to disengage an already activated muscle requires more brain processing power, and this directly correlates with the brain's ability to control muscles at the individual's decision.

Index Terms— Event Related Spectral Perturbation, Normal Go, Normal NoGo, Release Go, Release NoGo

Muscle deactivation in response to a decision requires higher processing power compared to muscle activation. Degeneration of Basal Ganglia is linked to a deficiency in sudden high cognitive decisions.

I. INTRODUCTION

THIS Project aims to investigate the cortical responses associated with muscle activation and deactivation. In this paper we will investigate the Event Related Spectral Perturbation (ERSP) in the context of muscle activation and deactivation when in response to Release Go/NoGo and Normal Go/NoGo stimuli. Event Related Synchronization and Event Related Desynchronization (ERS and ERD respectively) denote when there is an increase (ERS) or decrease (ERD) in synchronized oscillatory brain activity. ERS is associated with a state of cortical inhibition or “idle” state, while ERD is attributed to an increase in cortical activity and information processing or a “change” state [1]. We speculate that a difference in ERS will be present between a normal “Go” case and a release “Go” case, because of the inherent difference in decision making for activating and deactivating a muscle.

II. MATERIALS

A. Hardware/Physical Media -

We employ the ANT Neuro 64-channel electroencephalogram (EEG) model based on the international 10-10 system. This EEG uses Ag/AgCl electrodes for the channels. To facilitate the connection from the electrodes to the scalp, we use OneStep Cleargel. This is a conductive gel applied into the electrodes via syringe and reduces impedance. The EEG signal is amplified by an EEGO sport amplifier created by ANT Neuro. The electromyogram (EMG) model used is the BTS FREEEMG 300 produced by BTS Bioengineering. For our experiment, we only require 2 channels from this EMG. To mount onto the skin, we use the disposable electrode Vitrode M, a Ag/AgCl Solid Gel with Foam tape produced by Nihon Kohden. EMG data is collected via SMART-DX, a high-precision optoelectronic system for biomechanical motion analysis. An Arduino UNO R3 is used to execute the stimulus. An 8 channel trigger box is used to interface the Transistor-Transistor Logic (TTL) signals sent by the Arduino UNO R3 to SMART DX. To run the EEG software and power the Arduino, a 1866 Microsoft Surface Pro is utilized.

B. Software -

EEG data is collected via the EEGO software tool, developed by ANT Neuro. EEGLAB by Delorme & Makeig, 2004, is used for preprocessing and processing the data provided by EEG and EMG. All programs created to process and analyze the data were created using EEGLAB

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functions with MATLAB (MATLAB. (2023). Version R2023b. Natick, Massachusetts: The MathWorks Inc.). These programs, along with the Go / No Go task program ran in the Arduino can be found in the BioDynamics github repository [5].

III. METHODS

A. Set Up

Three healthy subjects that are right-arm dominant and about 170cm in height are selected. Each subject will participate in each trial of Normal Go/NoGo and Release Go/NoGo consecutively and only once. To begin, one subject is equipped with the EEG scalp and EMG one on the wrist flexor muscle group, and EMG two on the forearm flexor muscle group. The subject is seated at a table, with the stimulus display at eye level and 100 cm away from the subject. The subject's right arm is at rest on the table, with the back of the palm atop a support with palm upwards and thumb approximately 50 degrees from the vertical. The subject should be seated comfortably. After connecting the EEG to EEGO sport amplifier and initializing the EEGO software, the experimenter should adjust the scalp, input the conductive gel, and check impedance for each channel on eego software to verify stable and clear connection. Arduino TTL output should be connected to Smart DX for recording, via the 8 channel trigger box. This will record each event stimulus from the Arduino in relation to the EMG. The sampling rate of EEG is 2048 Hz, and the sampling rate of the EMG is 1000 Hz. EEG is sampled at a high frequency for precision at the ms scale. EMG is studied for muscle reaction time and does not require high precision.

B. Trials

Before beginning each trial, each subject must practice with the Go/NoGo signal without data being collected. This is to ensure consistent measurements, and reduce unnecessary flinch/noise, and otherwise bad data while recording.

The exercise grip task is as follows. The subject is set or rests to the trial baseline, and watches the screen for 10 seconds. In other words, for Normal Go/NoGo trial, the subject arrives or returns to the relaxed state with the exercise hand grip uncompressed, and vice versa for Release Go/NoGo. The subject will receive a ready signal that lasts between 2-5 seconds to prepare for the stimulus. The stimulus signal will last for 5 seconds. During this period, the subject must keep the state that was requested by the stimulus. For example, if the subject is participating in the Normal Go/NoGo trial, and is signaled "Go", for the 5 seconds the stimulus is on the screen, the subject must keep the grip compressed for 5 seconds to allow for consistent epochs. The Fig.1 visually represents the order and time in

which each prompt is activated. Note the timing variation of the ready state, between reset and the stimulus. To increase the experiment's effectiveness of recording the reactionary data to the stimulus, which is similar to an individual's sudden decision to initiate muscle activation/deactivation, or gait, a random variable is assigned with a range of 2-5 seconds to allow for this.

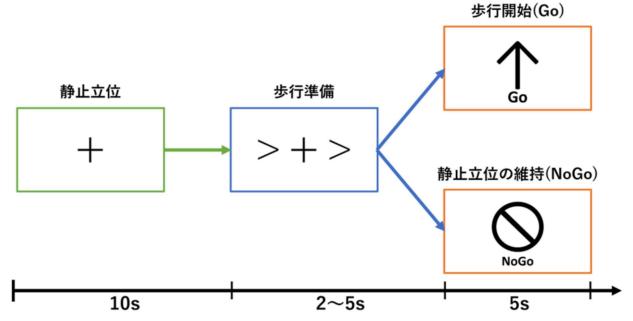


Figure 1: visual stimulus sequence

Once prepared for Normal Go/NoGo, the subject will follow the on-screen prompts and react as quickly as possible to the stimulus. The subject will complete 2 trial blocks each. The Normal Go/NoGo trial consists of two recordings with 12 Go and 12 NoGo events, randomly distributed throughout the trial. This totals 24 Go events, and 24 NoGo events for a Normal Go/NoGo trial. For Release Go/NoGo, it follows the same structure, with 2 recordings containing 12 Go/NoGo randomly distributed events each. Thus, a total of 96 events are produced. The subject will be provided adequate rest between recordings to reduce error from fatigue. This is believed to create an effective baseline for measurement and epoching. Further measurements may be effective, but require an increase in processing power and data acquisition uptime. Each recording is expected to take approximately 8 minutes to complete. This creates about 983,040 points of data for EEG, and 480,000 data points for EMG, per trial.

After completing the Normal Go/NoGo and Release Go/NoGo, the preparation and trial process will be repeated for the next subject until each subject has completed both trials.

C. Preprocessing

The EEG recordings on EEGO, and the arduino TTL and EMG recordings on Smart DX must be gathered together for computational analysis. A number of programs are created to perform and automate the following preprocessing actions as found in the BioDynamics repository [5].

1) Electroencephalogram Preprocessing

EEG data is uploaded to EEGLAB one at a time. The data is converted to a .set file, and channels are added following the 64-channel EEG 10-10 international system. The data is then high-pass filtered with a low cutoff of 1 Hz and an

upper cutoff of 60 Hz. Channels are removed based on if they flatline for 20 seconds or more, have a high frequency standard deviation of more than 6, and have a correlation less than 0.5 between nearby channels. These values were selected to prohibit significant noise and low frequency drift of channels, and to remove noisy channels. Any stricter criterion with correlation and standard deviation leads to critical channels being removed despite it containing relevant data. Figure 2 represents the filtered data. Independent Component Analysis (ICA) is run for artifact removal using the standard runica provided by EEGLAB. The file is then saved, and epochs surrounding “Go” and “NoGo” events are extracted. The epochs range from -2500ms to 2500ms around each event. ““Go” epochs are saved separately from “NoGo” epochs.

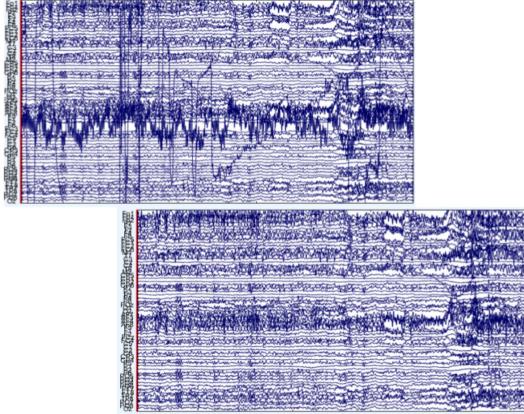


Figure 2: Comparison of Raw Data (Top) and Filtered and Noise Removed Data (Bottom)

2) Electromyogram Preprocessing -

To process EMG data in EEGLAB, the data for EMG and TTL must first be downloaded as a TDF file from SMART Analyzer, and converted to .CSV file. To eliminate latency between EEG and EMG and Arduino TTL, the initializing event must be synchronized between each file. This can be executed a number of ways, however we adjust the files via a program written in MATLAB. The EMG data is converted to a .set file containing only two channels [5]. The events from the EEG.set files are imported into the EMG.set file. The EMG data is then filtered between frequencies of 20 Hz to 450 Hz. This range is assumed to be effective in capturing the relevant data points [2]. To full wave rectification, each datapoint will be converted to positive as necessary via absolute value function. “Go” and “NoGo” Epochs are extracted in the same fashion as EEG.

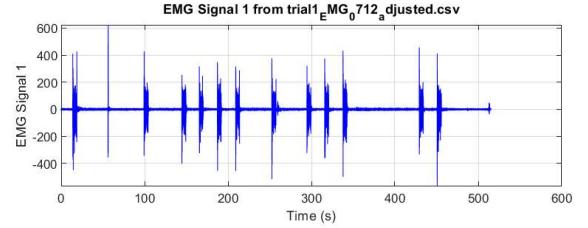


Figure 3: Wrist Flexor EMG example
Time (s)

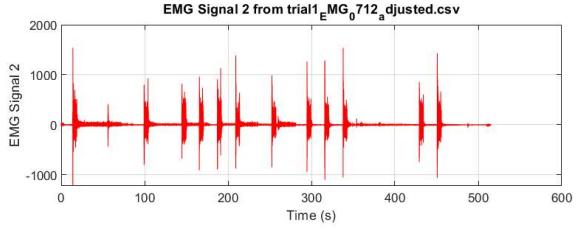


Figure 4: Forearm Flexor EMG example

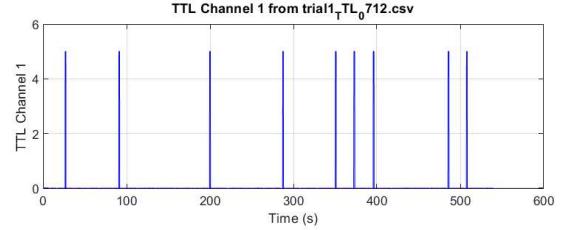


Figure 5: Arduino TTL Example

D. Processing -

The goal of this experiment is to observe the time frequency response of relevant channels from the EEG in response to a Normal Go/NoGo and Release Go/NoGo stimulus. EEG time frequency response will display changes in ERSP. EMG will be plotted alongside EEG time-frequency response, and will display time-microvolt response to depict muscle reaction. A number of programs written in MATLAB using EEGLAB functions will be employed to automate the following processing. These may be found in the repository as well [5].

1) Electroencephalogram Processing -

EEG epoch sets are first imported into EEGLAB. From these epochs, time-frequency response will be plotted surrounding the same epoch range of -2500ms to 2500ms around the stimulus. An example time-frequency plot is shown in Figure 6, where time (ms) is the x axis, and frequency (Hz) is the y axis. Frequency is plotted with a range of 0 Hz to 50Hz. Delta Band (0.5-4 Hz) has been determined to be associated with deep sleep and unconscious processes [3]. Theta Band (4-8 Hz) is associated with memory processes, navigation, or light sleep [3]. Alpha Band (8-13 Hz) represents awake relaxation and alertness [3]. Beta Band (13-30 Hz) is associated with active thinking, problem solving and motor

activity [3]. Gamma Band (30-100 Hz) is representative of high-level cognitive thinking such as attention, memory and perception. [3]. Due to the nature of our experiment requiring decision making, we will have a greater focus on frequencies within the Beta and Gamma bands.

The color on the Fig. 7 denotes ERSP. Red represents high ERSP, or ERS, and blue represents low ERSP, or ERD. Green is representative of ERSP around 0. To re-emphasize, ERS is important to our observations when determining the level of decision making as it represents a “change” state in the brain’s processes [1]. The channels selected to be analyzed are fixated in the left-center hemisphere of the brain. These channels include FT7, FC5, FC3, T7, C5, C3, TP7, CP5, and CP3. Based on If after preprocessing, the channel was deemed to be too noisy, the channel will be skipped from plotting. One channel is selected to represent this data, and will be averaged and plotted four times, based on Normal Go, Normal No Go, Release Go, and Release No Go.

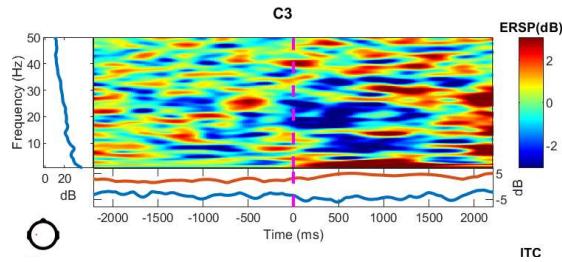


Figure 7: ERSP Example Plot

2) Electromyogram processing-

After sorting the epoch files based on its trial type (Normal Go/ Normal No Go, etc.), each epoch is plotted based on time and amplitude (microvolts). Both channels will be plotted and displayed as Forearm Flexor Group, and Wrist Flexor Group. From these graphs, the average for each trial type is plotted and will be paired with its EEG time-frequency response counterpart. Below in Fig. 8 shows an example of Normal Go without averaging.

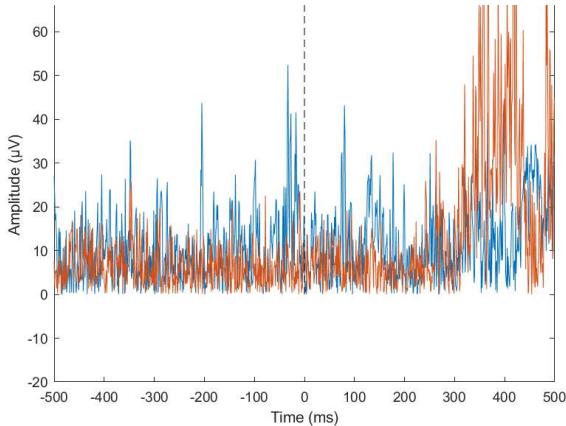


Figure 8: EMG Epoch around Normal “Go” signal

IV. RESULTS

A. Time-Frequency and Time-Amplitude Plots

The following figures depict average time-frequency and time-amplitude response of the EEG and EMG combined from each subject. Channel C3 is used to represent the average cortical response. This channel was selected due to its center placement and lack of noise. The time-amplitude plots are placed below its corresponding time-frequency plot, and plots EMG signal one (blue), and EMG signal two (red), the blue represents the Wrist Flexor Muscle Group, and the red represents the Forearm Flexor Muscle Group.

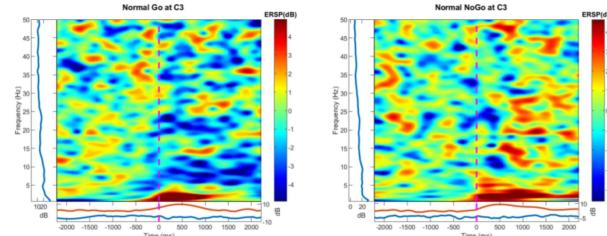


Figure 9: ERSP Normal Go (left) Normal NoGo (Right)

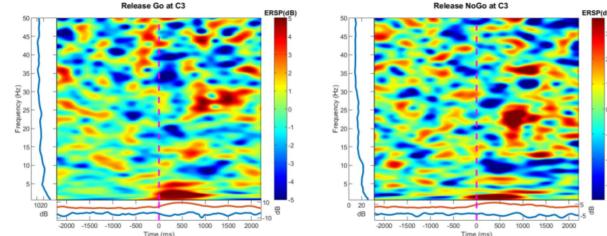


Figure 10: ERSP Release Go (left) Release NoGo (Right)

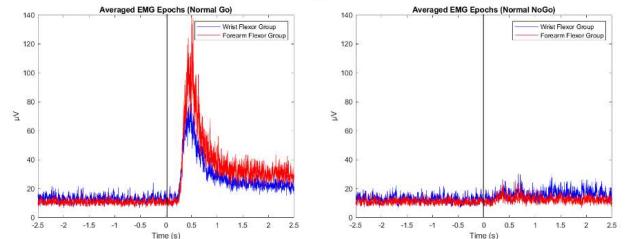


Figure 11: EMG Response Normal Go (left) Normal NoGo(Right)

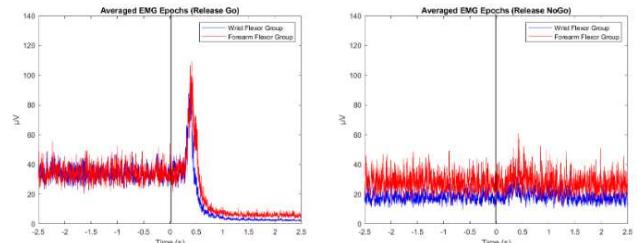


Figure 12: EMG Response Release Go (left) Release NoGo(Right)

B. Statistics

To contextualize and quantify the ERSP plots from Figures 9 and 10, Tables I, II, and III are available to provide data relevant to our analysis. ERD response will be the focus of our analysis . This data was extracted using programs that may be found in the BioDynamics repository [5].

Post Stimulus ERSP %	Normal Go	Release Go	Normal NoGo	Release NoGo
High (> 2dB)	2.05	10.05	9.25	4.42
Low (< -2dB)	35.49	18.71	13.38	18.75

Table I: Post Stimulus High and Low ERSP Percentage

Average ERSP across bands (dB)	Normal Go	Release Go	Normal NoGo	Release NoGo
Delta	0.02	1.33	1.96	0.98
Theta	-1.84	-0.19	0.49	-0.11
Alpha	-2.27	-0.98	-0.57	-1.48
Beta	-1.28	-0.26	-0.08	-0.36
Gamma	-1.34	-0.54	-0.2	-0.96

Table II: Average ERSP across Frequency Bands

Post Stimulus	Normal Go	Release Go	Normal NoGo	Release NoGo
Max ERSP Amp (dB)	6.62	7.99	5.3	4.62
Time (ms)	334.73	340.7	290.3	825.97
Min ERSP Amp (dB)	-7.88	-6.88	-6.25	-5.61
Time (ms)	2210	1049.61	334.7	2478

Table III: Maximum and Minimum ERSP

1) ERSP Analysis

Fig. 9 displays a contrast between the Release NoGo and Normal NoGo in ERSP. Post Stimulus, we observe that Normal NoGo compared to Normal Go produces significantly less brain processing as noted in ERD (blue). Comparatively, Fig. 10 shows Release NoGo and Release Go produce around the same ERD, within Delta, Theta, and Gamma.

From our statistics, we gather that Normal Go produces a ERSP maximum of 6.62dB and an ERSP minimum of -7.88dB. When comparing Release Go to Normal Go, we see an increase in Maximum ERSP Amplitude at 7.99dB, but a decrease in minimum amplitude at -6.88dB. Conversely, we observe a decrease in ERSP maximum and minimum amplitude between Normal NoGo and Release NoGo. In the Gamma Band, we observe that Release NoGo actually produces a higher ERD response at an average of -0.96dB than both Normal NoGo at -0.2dB, and its Go counterpart at -0.54dB. Fig. 13 allows us to visualize the average ERSP across frequency bands post-stimulus. Note that Normal Go produces the most significant ERSP average in the negative as ERD. The rest of the trials

produce positive Delta band ERSP, and are relatively close in terms of average ERSP. It appears that compared to Normal Go in the Gamma Band, Release NoGo produces the second lowest ERSP average, or ERD. Observing the post-stimulus distribution percentage of change in power relative to the baseline period for each frequency band plotted on Fig. 14, we find that Normal Go produces the highest percentage of low ERSP, and the lowest percentage of high ERSP. We may also observe that Release Go and Release No/Go produce a similar low ERSP percentage, but that Release Go produces higher ERSP average.

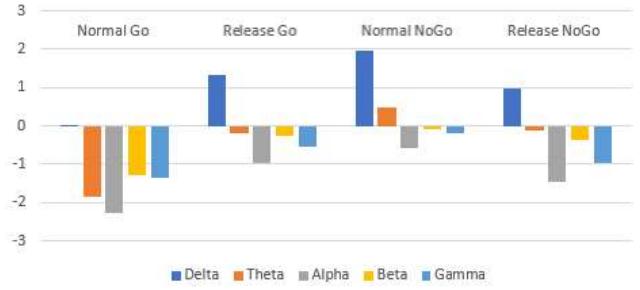


Figure 13: Post Stimulus Average ERSP for each Frequency Band as dB

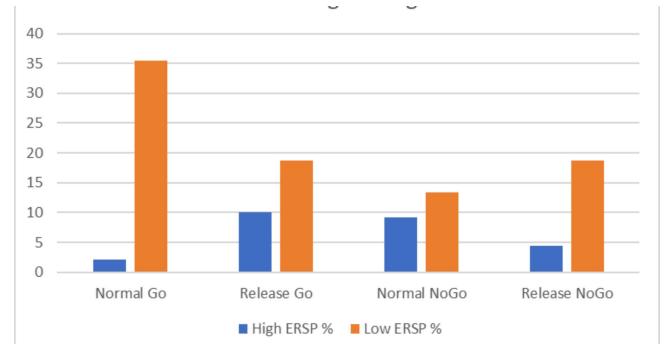


Figure 14: Post stimulus Percentage of High and Low ERSP

2) EMG Time-Amplitude Analysis

The average reaction time post stimulus for the Normal trials range around 250ms, whereas the average reaction time for the Release trials ranges from 300ms. Interestingly, instead of observing a sudden drop post-stimulus for Release Go, we see a spike in EMG response, then followed by a drop.

V. DISCUSSION

Although we observe a greater maximum and minimum peak within Normal NoGo compared to Release NoGo, the clear difference between average percentage of high and low ERSP post stimulation. Release NoGo has a marginally larger percentage of ERD post stimulus in comparison to Normal NoGo. Because ERD is associated with a state change, or in other words, processing, we can determine that the release or deactivation of a muscle inherently requires more processing power. Looking at the frequency band distribution. Release NoGo compared to Normal NoGo has a significantly larger average ERD measurement. This furthers our hypothesis that the decision between

Release Go and Release NoGo is a harder task than the Normal Go and Normal NoGo.

Regarding EMG response, the increase in reaction time to the Release Go/NoGo stimulus is concurrent with the idea that a muscle deactivation sequence requires more of the brain's concentration. The spike response post Release Go-stimulus is believed to be an artifact seen from initial arm movement from a flexed to relaxed position. However, further studies around muscle deactivation is recommended to verify if muscle activation is required prior to deactivation.

VI. CONCLUSION

In our muscle deactivation case of Release Go/NoGo, it is evident that the decision making process requires a larger depth of processing, as well as longer time from mind to muscle trigger, compared to a Normal Go/NoGo signal. Current studies show that PD patients produce weaker ERD responses for Normal Go/NoGo trials [4]. Thus, we conclude that an inability to initialize gait is related to the brain's ability to process decisions at a high cognitive level. PD patients encounter gait freeze, as well as other impaired motor functions when requiring muscle deactivation.

SUPPLEMENTARY MATERIALS

MATLAB

The analyses were conducted using MATLAB version R2023b, a high-level programming environment developed by The MathWorks Inc. MATLAB was utilized for implementing the analysis pipeline and visualizing the results.

EEGLAB

Data analysis was performed using EEGLAB version 202.0, an open-source MATLAB toolbox developed by Arnaud Delorme and Scott Makeig. EEGLAB provides tools for processing EEG data including independent component analysis and time-frequency analysis (Delorme & Makeig, 2004).

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