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MAVIN: an open-source tool for interactive analysis and visualization of EMG data

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Letter to the Editor

Quantification of motor evoked potentials (MEP) has been a cornerstone of non-invasive brain stimulation research since its creation. In the first demonstration of non-invasive brain stimulation, Merton & Morton (1980) quantified peripheral MEPs to demonstrate that transcranial electric current stimulation (tECS) of the motor cortex would evoke a peripheral contraction in the hand. Barker and colleagues (1985) also used the MEP to demonstrate, for the first time, that it was possible to evoke a peripheral MEP via transcranial magnetic stimulation (TMS). Now, 30 years later the MEP has become the primary dependent measure for the majority of single and paired pulse studies of cortical excitability in healthy individuals as well as patient populations. Additionally, as repetitive TMS is being embraced internationally as a treatment for psychiatric disease, device manufacturers are beginning to integrate MEP quantification into their instrumentation. This enables clinicians to rely on a more sensitive, quantifiable measure to determine the motor threshold than visual inspection alone.

However, despite its increasing usage as a tool for both “precision medicine” and precision science, there are very few automated, open access data analysis tools for basic and clinical science researchers. Common dependent measures in the field include: the amplitude and latency of the MEP at baseline or after an intervention, intracortical inhibition and facilitation following paired pulse stimulation, the length of the cortical silent period or the shape of the recruitment curve. Analyzing these data often includes identifying artifacts from a transcranial magnetic stimulation (TMS) trigger pulse and computing characteristics of an individual’s response by hand or using custom scripts, a time-consuming process which is subject to inter-examiner variability and has doubtless resulted in duplication of efforts.

To address the need for automation we have developed MAVIN - a freely available motor evoked potential analysis and visualization instrument

MAVIN provides rapid visualization and analysis for EMG data. In its current version, MAVIN can load, analyse and visualize electromyographic (EMG) data from Spike2 (.smr). It is possible to visualize a long train of EMG signals or a subset of the data that is loaded. The analysis feature has four different modes: basic EMG/paired associative stimulation (PAS), paired-pulse (PP), cortical silent period (CSP), and recruitment curve (RC). While the current version of MAVIN easily reads Spike2 formatted data, this is an open source platform which can be customized for various data input sources. Future iterations can be made compatible with different input sources including CSV and other commercial outputs based on user feedback to the developers and the community of users at large.

Features

- For basic MEP measurement studies and paired associative stimulation (PAS), the MAVIN can quantify the MEP amplitude and latency after each TMS pulse and average subsets of these values at the end of the run for each subject. MAVIN identifies each TMS trigger artifact, searches within an adjustable window for the highest and lowest signal voltages during that window (known as the peak-to-peak amplitude), and computes the averages of a subset of MEP amplitudes. These data are reported in a window of the application, and optionally written to disk in the CSV format.
- For paired pulse studies (PP), the MAVIN analysis provides averages and standard deviations of the MEP, as well as Interhemispheric inhibition (PP- IHI) and interhemispheric facilitation (PP-IHF). These data can be saved and compared across sessions.
- For cortical silent period studies, the MAVIN detects the TMS artifacts and finds the longest interval under a certain (adjustable) voltage threshold within a temporal window using a variant of the algorithm described in Julkunen 2013.
- For the recruitment curve, the MAVIN computes and plots the average MEP amplitude for each intensity. A sigmoid function is fit to these data, from which useful metrics such as maximum slope and plateau can be found.

Analysis validation

In order to compare the results of MAVIN with the previous methods used in the field we applied MAVIN to a set of recently published data (Hanlon et al 2015) from our laboratory which had been analyzed with a combination of custom scripts and manual calculation. In

this paired-pulse TMS study, IHI (3ms delay) and IHF (15 ms delay) had been quantified in a group of 41 healthy controls and substance dependent individuals. For each subject, paired-pulse average MEPs were measured for 3 different TMS stimulation intervals for both left and right hand, yielding 230 average MEP data points in total. A trainee in the laboratory that was blinded to the participant characteristics or the results from the published manuscript (which was under review at the time) analyzed the entire paired-pulse data set using MAVIN. The data was analyzed in a batch including all participants. The analysis for the entire group was complete within 60 seconds. Using the published data as a reference point, we found that MAVIN detected the paired-pulse IHI and IHF MEP averages swiftly and robustly. There was no significant difference between the results of the published data and MAVIN's automated routine (mean error of 0.078 mV, standard deviation of 0.093 mV, CCI=0.996).

Technical Details

A 64-bit Windows version of the tool is available for download at <https://sites.google.com/site/thehanlonlab/mavin>. The source code is also available for download on other operating systems capable of running Python 2.7.9. including Windows, MacOS X, and Unix/Linux. Questions about the tool should be addressed to the corresponding author.

In summary, we would like to notify the brain stimulation field of a new, open source tool for analysis and visualization of EMG data that is commonly acquired in basic neuroscience studies of cortical excitability as well as in clinical studies which use the motor evoked potential as a dosing metric for repetitive TMS studies. This automated tool is able to robustly detect artifacts in the EMG data and rapidly analyzes large sets data with results similar to manual calculation.

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Figure 1.