BEST Toolbox: Brain Electrophysiological recording & STimulation Toolbox

www.best-toolbox.org

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1. Introduction and Value Proposition

- ❑ Non-invasive brain stimulation (NIBS) experiments involve many standard procedures that are nonetheless not sufficiently standardized in the community.
- ❑ Transcranial magnetic stimulation (TMS) protocols usually require ***motor hotspot search***, ***motor threshold hunting***, ***motor evoked potential*** (MEP) and ***TMS-evoked EEG potential*** (TEP) measurements, estimation of ***stimulus-response curves, paired-pulse TMS***, ***rTMS intervention protocols***, etc., and since recently also ***brain state-dependent or real-time EEG-triggered stimulation.***
- ❑ Given the diversity in application and experience of experimenter, standardized, automated, and yet flexible, data collection and analysis tools are needed that facilitates intuitive experimental design, integrate experimental conditions and stimulation parameters in an efficient manner, and equip a novice user of brain stimulation protocols with state-of-the-art approaches in the field.
- ❑ Here, we introduce the **Brain Electrophysiological recording and STimulation (BEST) Toolbox**, a **MATLAB** based **open source** software that interfaces directly with peripheral EEG, EMG, and (via the MAGIC toolbox[1]) TMS devices, and thus allows to run flexibly configured but fully automated **closed-loop protocols.**
- ❑ BEST Toolbox facilitates its users with **experimental design**, **session management**, saving and loading previously designed experiments or templates of experimental conditions with built in folders and **data management** at a provided root directory. The BEST toolbox also allows to load results from previously conducted protocol and link the resultant parameters to upcoming protocols.
- ❑ Such capabilities of BEST Toolbox also enable its users to **practice open science**, **facilitate reproducibility** and **standardize training methodologies** in the community.

2. Hardware-Software Interface

Input Devices

The BEST toolbox is compatible with following EXG and behavioral acquisition systems:

- ❑ Bittium NeurOne TESLA
- ❑ Brain Products actiCHamp
- ❑ FieldTrip Real-Time Buffer[2]
- ❑ Recording button boxes (Serial/TTL)
- ❑ Keyboards
- ❑ CED 1401 (in progress)

Output Devices

The BEST toolbox is designed to work with any stimulation device that accepts TTL as an input signal, since the BEST toolbox sends TTL pulse(s) via:

- ❑ Host PC
- ❑ Arduino
- ❑ Raspberry Pi
- ❑ sync2brain bossdevice

For MagVenture and MagStim TMS devices also stimulation parameters can be configured online.

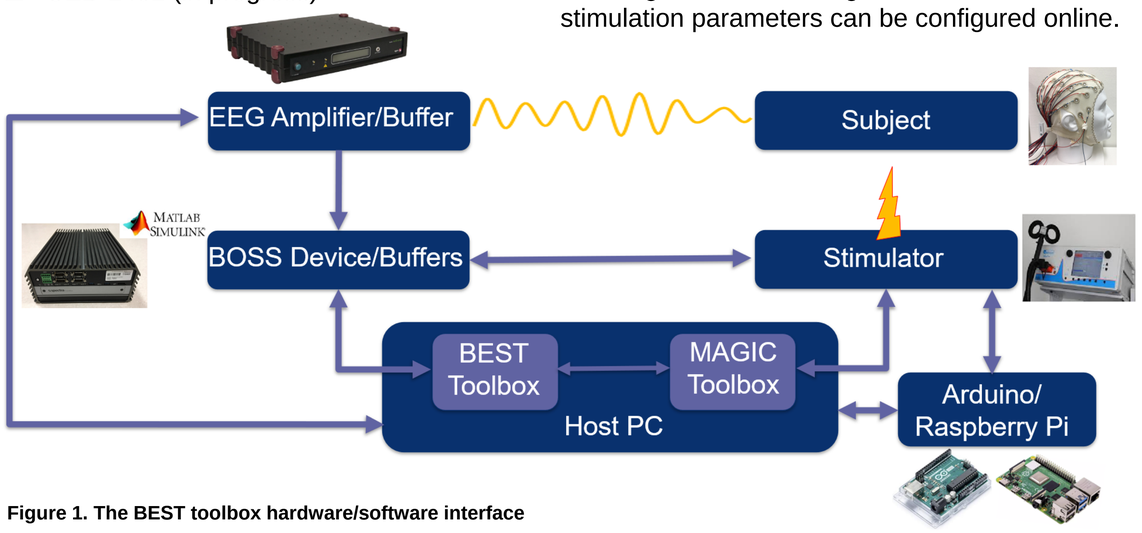

Figure 1. The BEST toolbox hardware/software interface

3. Toolbox Features

The BEST toolbox currently comprises 11 high level protocols, designed to be executed in any sequence and number of repetitions desired for the experimental design via a graphical interface application.

- ❑ MEP Hotspot Search
- ❑ MEP Threshold Hunting
- ❑ MEP Dose Response Curve
- ❑ MEP Measurement
- ❑ rs EEG Measurement
- ❑ TMS-fMRI Measurement
- ❑ Sensory Threshold Hunting
- ❑ TEP Hotspot Search
- ❑ TEP Measurement
- ❑ ERP Measurement
- ❑ rTMS Intervention

Most of these protocols can also be performed in a brain state-dependent (i.e., EEG phase- and/or power-triggered) manner, given the availability of the required hardware.

4. Application Overview

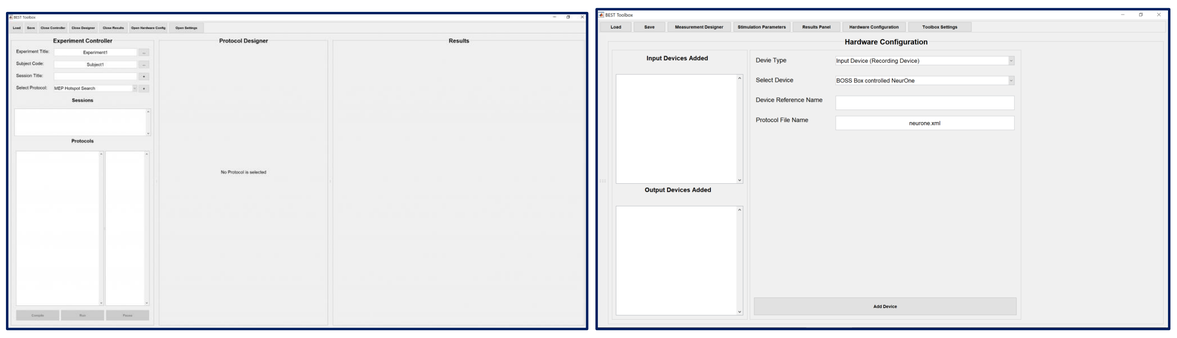

Figure 2. The BEST toolbox application overview. Launch View (top left), Hardware Configuration Area (top right), Protocol Parameters area (bottom left), Real-time results dashboard (bottom right)

5. Dependencies

The BEST Toolbox application is compatible with any MATLAB version newer than **r2006**, however MATLAB version should exactly be r2017b when the BEST Toolbox shall be used in combination with the bossdevice (e.g. for brain state-dependent protocols).

- ❑ bossdevice API
- ❑ MAGIC[1]
- ❑ FieldTrip Toolbox[2]
- ❑ Simulink Real-Time*
- ❑ Simulink Coder *

* only for sync2brain's bossdevice

6. The Graphical User Interface (GUI) and Functionality

- ❑ Interactive graphical and tabular *condition designer* for designing complex experimental conditions as shown in Figure 3.

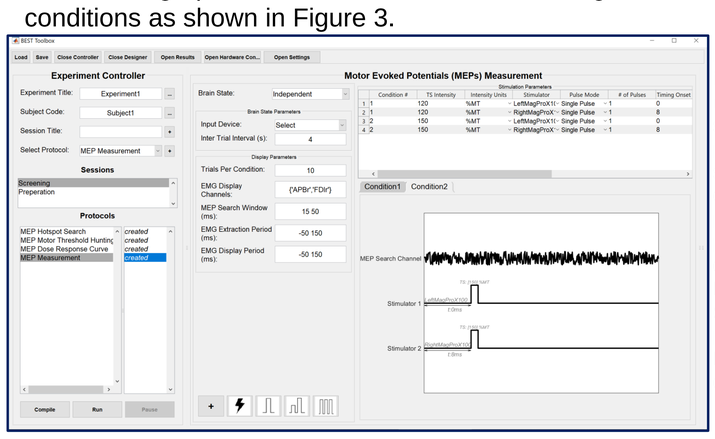

Figure 3. The BEST toolbox application interactive conditions designer for multimodal experiment design. Multiple stimulators of different type, multiple pulses, stimulation intensities, inter-stimulus and inter-trial intervals can be configured interactively. Also single-coil paired-pulse and dual-coil protocols are possible. In this case, the condition is designed for two coils placed on left & right M1 to perform interhemispheric inhibition (IHI) with 8ms ISI. Similarly, any other paired-pulse TMS protocol, such as SICI, LICF, ICF, LICI, SAI, LAI, etc. can easily be designed.

- ❑ Interactive and versatile *results dashboard* tailored for each protocol to visualize results of protocol and online interact with them to ensure quality data acquisition as shown in Figure 4.

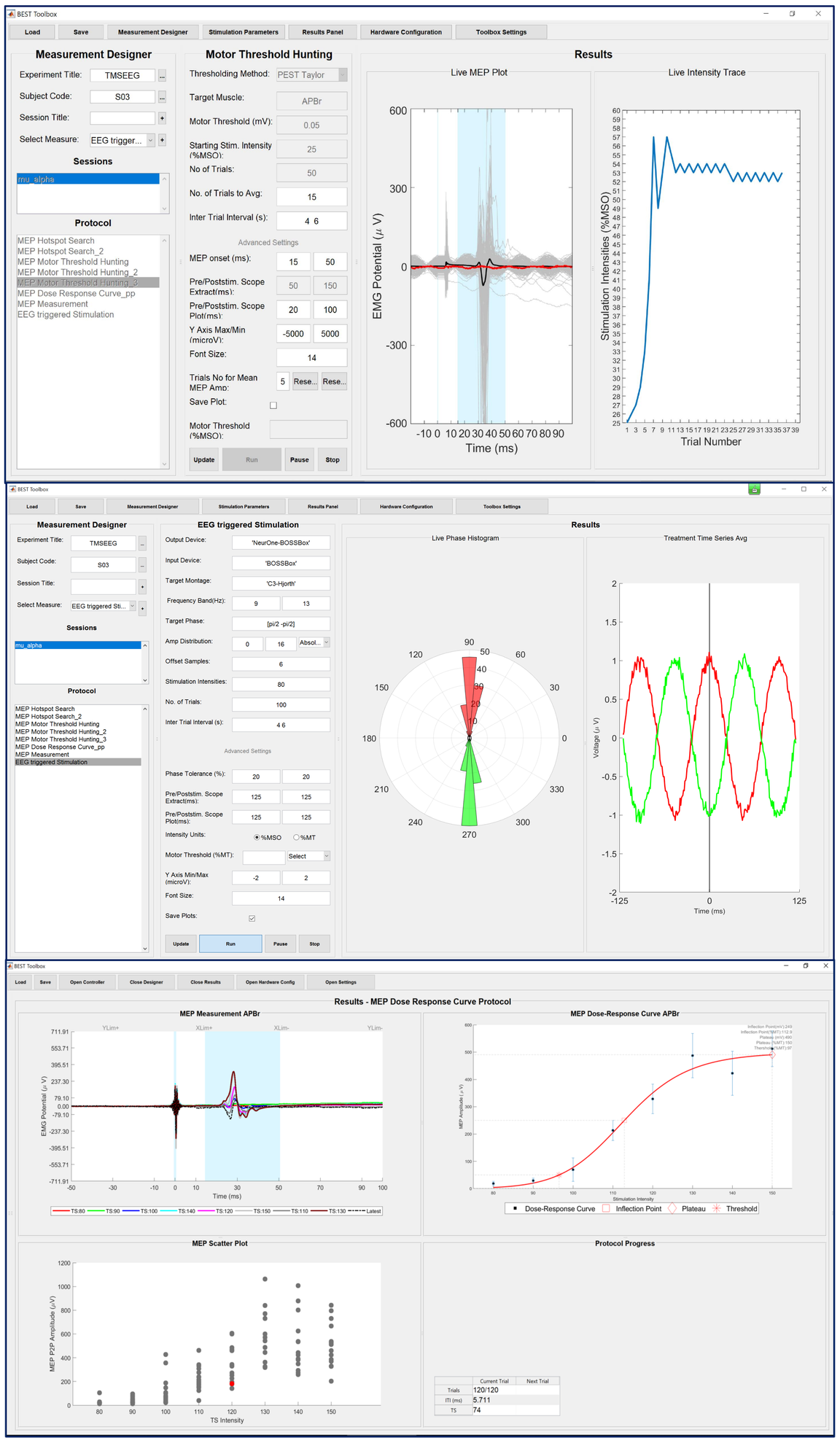

Figure 4. The BEST toolbox application visualizing data in real-time as execution of the protocol progresses. **Upper panel:** Automated determination of the resting motor threshold (RMT) via a closed-loop adaptive staircasing procedure in a single subject (real MEP data), visualizing recorded MEPs (left) and trace of stimulation intensities (right). **Middle panel:** EEG-triggered TMS targeting peaks (red) and troughs (green) of a 10 Hz oscillation (simulated input data), visualizing target phase histograms (left) and time-locked averages (right). **Lower panel:** Automated determination of dose-response curve in a single subject (real MEP data), visualizing recorded MEPs averages per condition (top left), sigmoid fitted curve with annotated inflection point and plateau (top right), scatter plot of individual MEPs (bottom left), and protocol progress (bottom right).

5. References

1. Saatlou et al., 2018. MAGIC: An open-source MATLAB toolbox for external control of transcranial magnetic stimulation devices. Brain Stimulation: Basic, Translational, and Clinical Research in Neuromodulation.
2. Oostenveld et al., 2011. FieldTrip: open source software for advanced analysis of MEG, EEG, and invasive electrophysiological data. Computational intelligence and neuroscience.