A two stage process for improving Brain-Computer Interface outcomes

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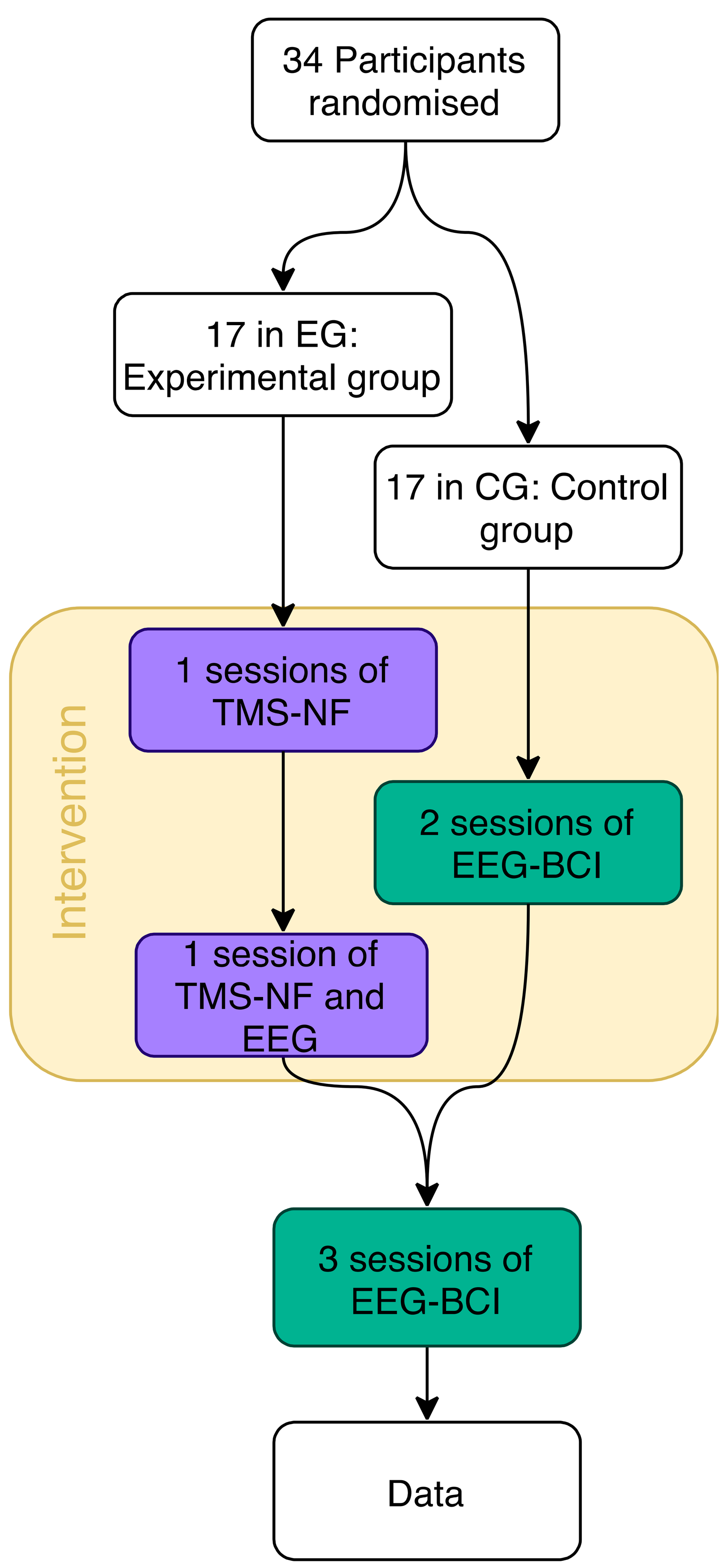
BACKGROUND

- Most types of Brain Computer Interfaces (BCI) for neurorehabilitation use Electroencephalography (EEG) to detect brain activation patterns deemed beneficial for recovery
- These systems take many (5-8) sessions before the BCI can be used effectively, as it needs to adapt to individual patterns of brain activity
- Using other brain derived signals such as Motor Evoked Potentials (MEPs), elicited by Transcranial Magnetic Stimulation (TMS) as Neurofeedback (TMS-NF) healthy participants can achieve control over the BCI within 2 days (Ruddy et al., 2018)
- The trained brain states were associated with distinct patterns of neural oscillations within the motor network (Ruddy et al., 2018)
- Here we will test whether it is possible to use a pattern of brain activity learned during TMS-NF to feed into a two-staged BCI that can be used to pre-train participants before using a traditional EEG-BCI system, such that they would learn faster and with greater success

METHOD

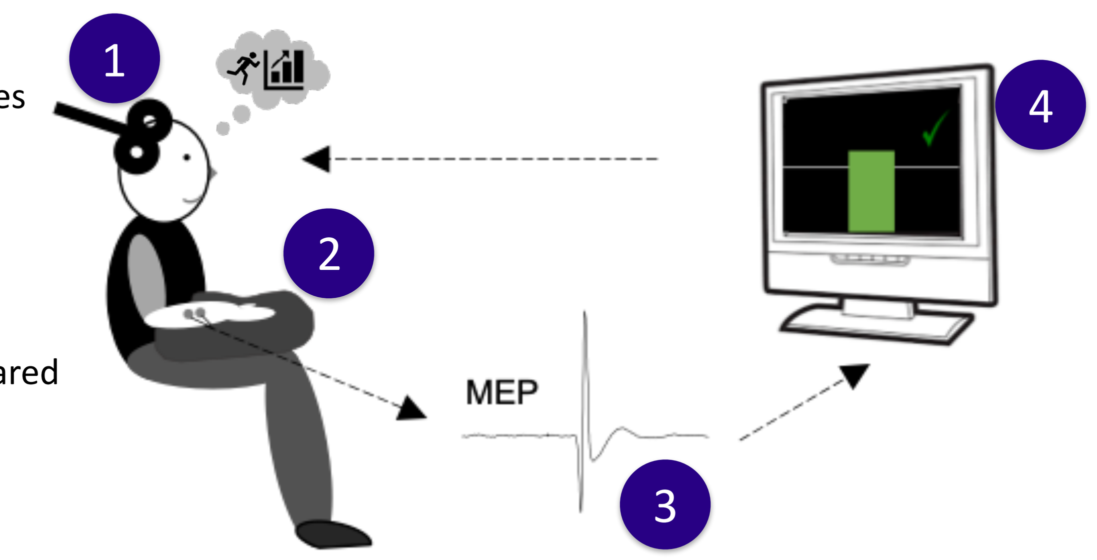


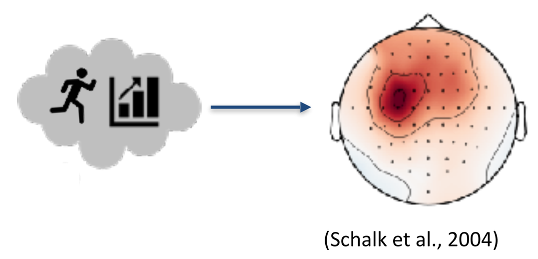
- 34 participants are needed
- Based on a sample size calculation assuming a predicted effect size of d=0.97 (MEP Neurofeedback effect size from Ruddy et al., 2018)
- 2 groups matched on motor imagery ability using Motor Imagery Questionnaire (MIQ-RS, Butler et al., 2012)
- Experimental group will have 2 sessions of TMS-NF
- The TMS-NF blocks are made up of 4-6 blocks with 30 trials
- Second TMS-NF session collects TMS Evoked Potentials (TEPs), the brain's EEG response to the TMS pulse
- Control group will have 5 sessions of EEG-BCI
- To test if TMS-NF can pre-train participants before using a EEG-BCI system, *success rate, learning rate, and classification accuracy* between the two groups and their system will be compared

EXPERIMENTAL GROUP

TMS-NF

1. Transcranial Magnetic Stimulation (TMS) evokes Motor Evoked Potential (MEP)
2. MEP is recorded by Electromyography
3. MEP amplitude is compared to baseline
4. Feedback is displayed to participant





TMS-NF control scheme

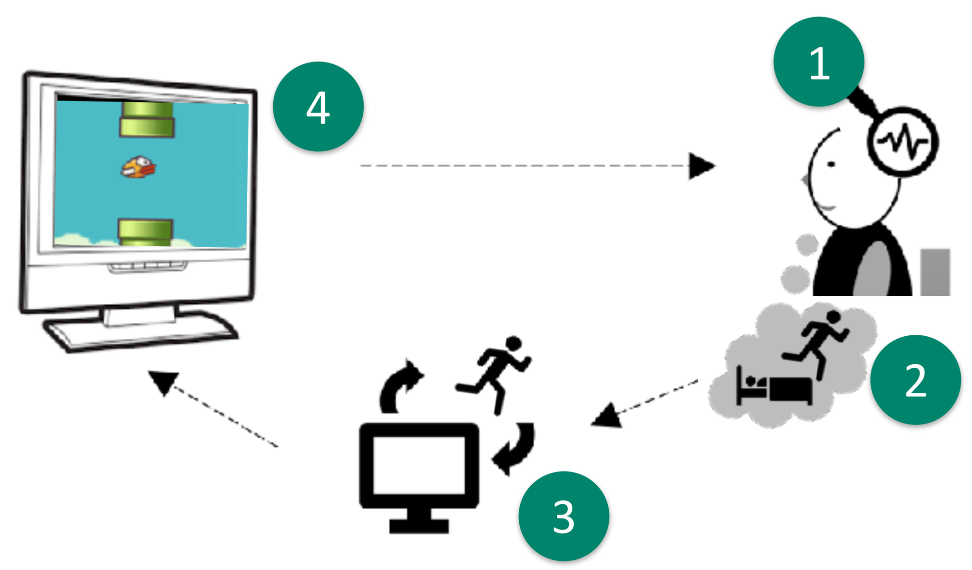
The experimental group will have two sessions of TMS-NF. The last session of TMS-NF will include record EEG recordings.

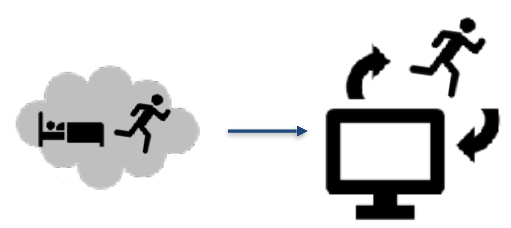
Using a Common Spatial Patterns (CSP) approach the state responsible for MEPs with high amplitudes will be determined and used to drive the EEG-BCI sessions for the experimental group.

CONTROL GROUP

EEG-BCI

1. Acquire EEG signals during rest and motor imagery
2. Differentiate electrophysiological patterns for these two states using CSP
3. Display feedback to participant in computer game to train them to achieve control of BCI.



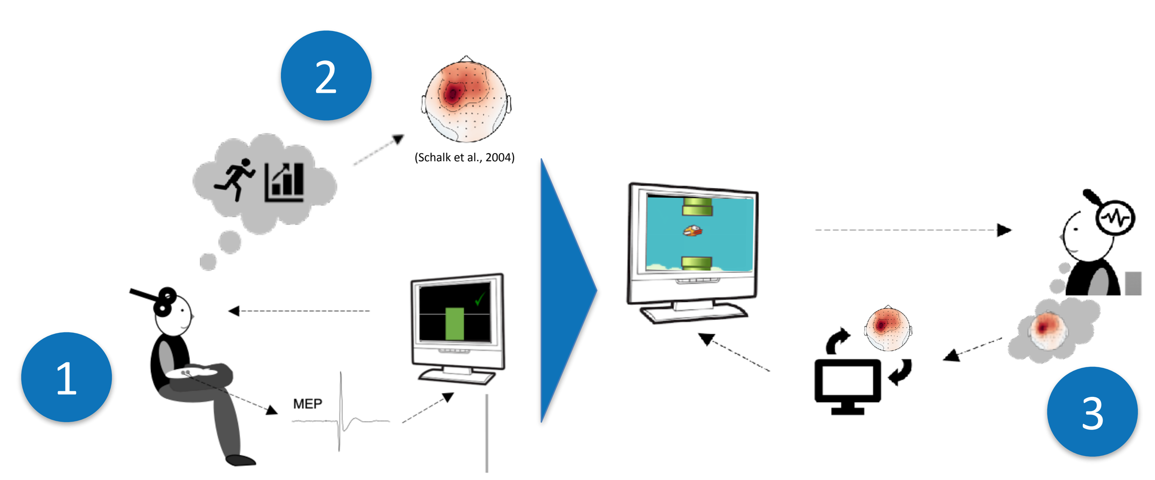


EEG-BCI control scheme

The control group BCI will also use CSP, calibrated by two different mental states- resting EEG and Motor Imagery.

TWO STAGES: COMBINED APPROACH

1. Two sessions of TMS-NF
2. Acquire CSP of maximal MEP amplitudes
3. Use CSP for Motor Imagery BCI



HYPOTHESES

(H1) TMS-NF will be a faster and, or more efficient way to train participants for EEG-BCI

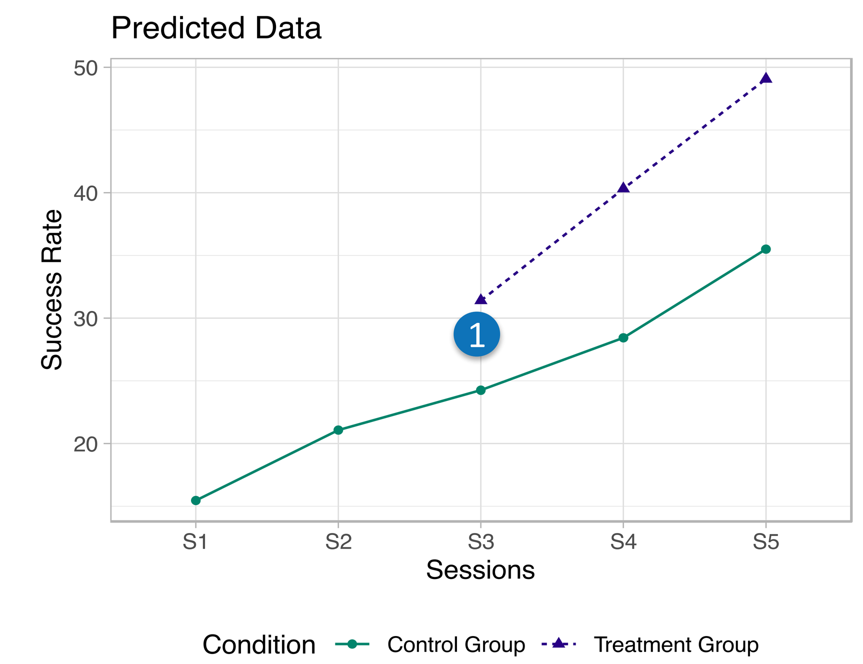
(H2) CSP can be used to find a state responsible for high MEP amplitudes and can be used as EEG-BCI driver

(H3) The groups will show differences in topography or oscillations, and classification accuracy rates

ANALYSIS

This section discusses *hypothesised* study outcomes (data collection has not yet occured).

EEG-BCI Success Rate (H1)



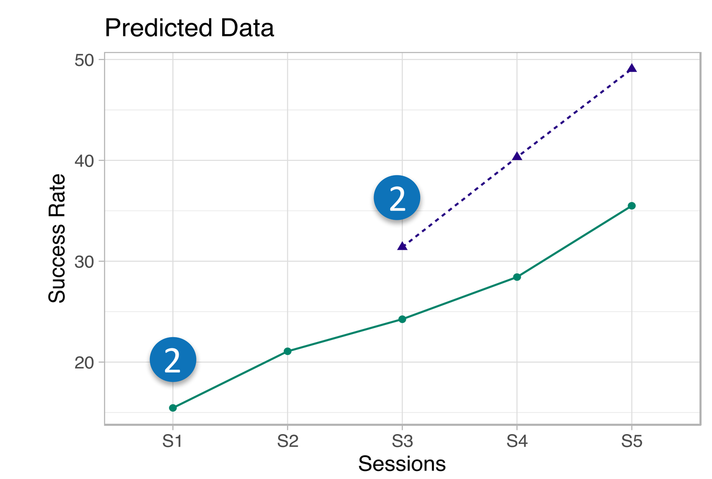
To investigate success rates between groups, there are three interesting comparisons:

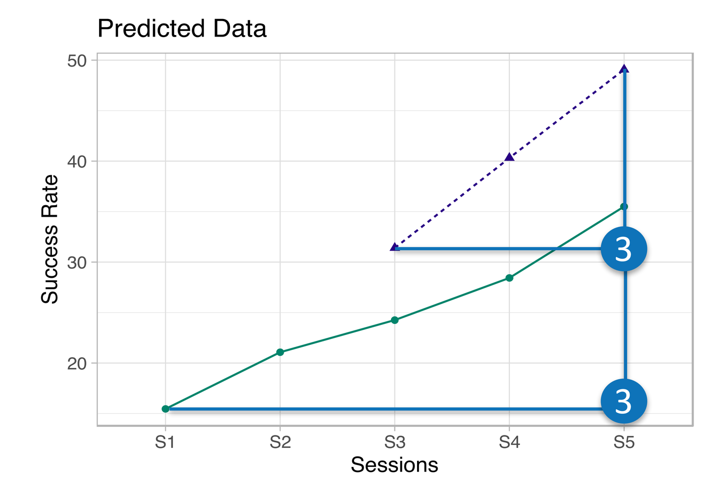
- Comparison 1: EEG-BCI success rate between the two groups at Session 3

This shows if two sessions of TMS-NF are more efficient than two traditional EEG-BCI sessions for success rates of EEG-BCI.

- Comparison 2: EEG-BCI success rate between TG, session 3 and CG session 1

This shows if TMS-NF can be used to pretrain participants for the use of EEG-BCI.

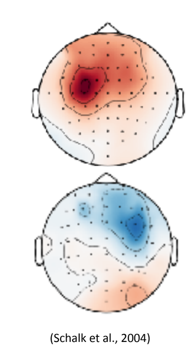




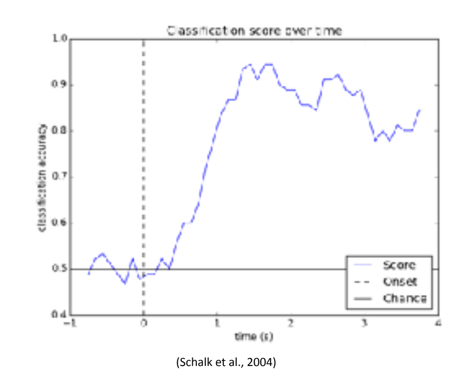
- Comparison 3: Slope of learning curve between TG and CG

This shows if TMS-NF helps participants to learn how to use the EEG-BCI faster.

BCI Drivers (H2 & H3)



- Control group and experimental group used different controls for the EEG-BCI
- Differences in topography, oscillations and successful state categorisation between the groups could be related to the perfomance



CONCLUSIONS

- TMS-NF *could* be an alternative way to train participants for EEG-BCI use. The MEP feedback from TMS-NF could be valuable for participants who have difficulties using traditional EEG-BCI (for example due to a brain injury)
- The quick and successful transition from TMS-NF to EEG-BCI *could* enable a two step programme for BCI using a portable EEG-BCI for homebased, patient driven neurorehabilitation, after TMS-NF training

REFERENCES: Ruddy, K., Balsters, J., Mantini, D., Liu, Q., Kassraian-Fard, P., Enz, N., Mihelj, E., Subhash Chander, B., Soekadar, S. R., & Wenderoth, N. (2018). Neural activity related to volitional regulation of cortical excitability. *ELife*, *7*, e40843. https://doi.org/10.7554/eLife.40843 Schalk, G., McFarland, D. J., Hinterberger, T., Birbaumer, N., & Wolpaw, J. R. (2004). BCI2000: A general-purpose brain-computer interface (BCI) system. *IEEE Transactions on Biomedical Engineering*, *51*(6), 1034–1043. https://doi.org/10.1109/TBME.2004.827072