MODULE 3-P2: TMS-based decoding of executed hand actions in Asian healthy adults

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1 Introduction

- Transcranial magnetic stimulation (TMS)-based neurofeedback (NF) with motor imagery (MI) can be used for training individuals to volitionally modulate sensorimotor activity of individual finger movements without producing overt movements [1, 2, 3].
- Selective TMS-based classifiers are suitable for decoding imagined single finger movements [1].
- However, complex daily-life actions performed with the hand require selective activity of the wrist and fingers. **To enable TMS-based NF with MI for daily-life actions that require facilitating more than a single muscle, the first step requires identification of the appropriate muscle facilitation patterns via motor execution.**
- **Aim**: To identify specific facilitation patterns evoked by TMS during action execution.
  - **Hypotheses**:
    1. Executed action-specific facilitation patterns can be identified by classifiers using machine learning approaches.
    2. Facilitation patterns are generalizable between left and right hands.
    3. Facilitation patterns are generalizable across participants.

2 Preliminary work

- Participants: One male (27 years old) and two females (32 and 24 years old).

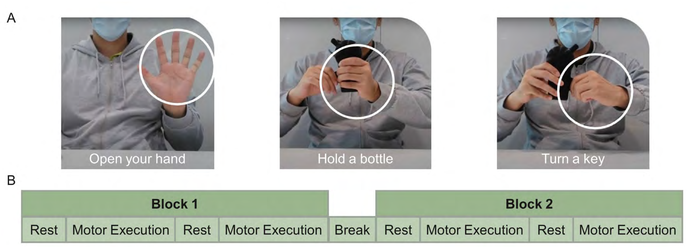

Figure 1: Experimental protocol. (A) Three actions performed with the hand were selected for the preliminary work based on their relatively high usage in daily life, namely hand opening, holding a bottle, and turning a key. (B) Participants were instructed to perform the cued action for two blocks within a session using their right hand. Within each block, there were 20 rest trials and 48 motor execution trials (i.e., 16 trials per action), with a 30-second break after 34 trials. Participants performed two sessions on separate days.

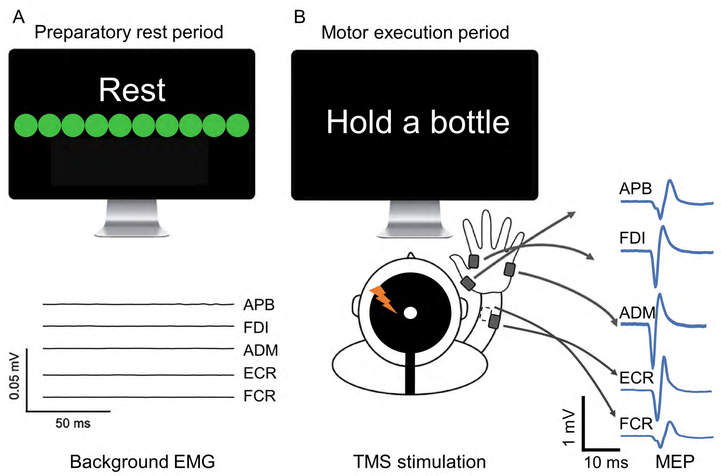

Figure 2: Schematic experimental setup. (**A**) Preparatory rest period. Participants are instructed to rest and ten dots represent the background electromyography (EMG) in the recorded muscles (from left to right = left abductor digiti minimi (ADM), left first dorsal interosseous (FDI), left abductor pollicis brevis (APB), left extensor carpi radialis (ECR), left flexor carpi radialis (FCR), right APB, right FDI, right ADM, right ECR, and right FCR). (**B**) Motor execution period. A start cue appears and participants are instructed to perform the cued action with their right hand. Actions are sustained until the TMS pulse is discharged.

3 Preliminary findings

- Data normalization: Motor evoked potentials (MEPs) recorded from a given muscle were divided by the mean of all MEPs acquired from that muscle during action execution trials in a session.

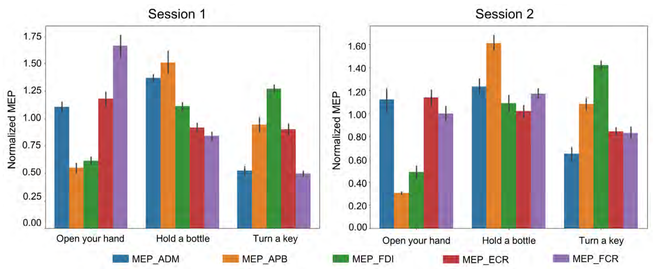

Figure 3: Muscle-specific normalized MEP patterns of three actions in a representative participant. Upon visual inspection, the normalized MEP patterns of the three finger muscles (i.e., APB, FDI, and ADM) appeared to be similar between sessions. However, the normalized MEP pattern of wrist muscles (i.e., ECR and FCR) appeared to be more variable.

- Subject-specific classification of executed actions: A support vector machine (SVM) was applied to classify the normalized MEP patterns of three hand actions (balanced classes).

Table 1: Intra- and inter-session accuracies for three participants.

	Intra-session accuracy		Inter-session accuracy	
Participant	**Session 1**	**Session 2**	**Session 1**	**Session 2**
1	95%	94%	92%	80%
2	82%	94%	58%	50%
3	97%	97%	88%	82%

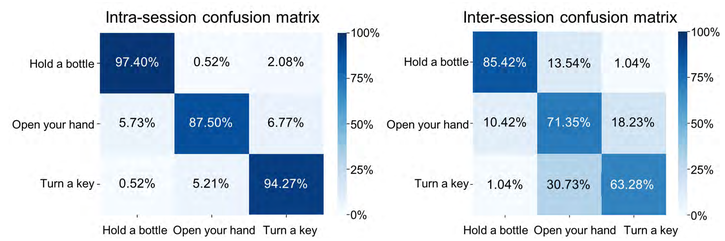

Figure 4: Average intra- and inter-session confusion matrices across all participants. An SVM-based classifier could decode executed daily-life actions based on muscle-specific normalized MEP patterns.

4 Future work

Preliminary work

Aim: To identify executed action-specific facilitation patterns evoked by TMS.

Pilot experiment

Aim: To optimize the robustness, correctness and usability of the identified action-specific facilitation patterns for TMS-based NF with MI.

Experiment 1 – a proof-of-concept study

Aim: To investigate how TMS-based NF with MI influences neural activity patterns in the brain.

References:

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[2] K. Ruddy, J. Balsters, D. Mantini, Q. Liu, P. Kassraian-Fard, N. Enz, E. Mihelj, B. Subhash Chander, S. R. Soekadar, and N. Wenderoth, “Neural activity related to volitional regulation of cortical excitability,” eLife, vol. 7, 2018.

[3] W. D. Liang, Y. Xu, J. Schmidt, L. X. Zhang, and K. L. Ruddy, “Upregulating excitability of corticospinal pathways in stroke patients using TMS Neurofeedback; a pilot study,” NeuroImage: Clinical, vol. 28, p. 102465, 2020.

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