Connectivity between the supplementary motor area and primary motor cortex: paired-pulse transcranial magnetic stimulation (ppTMS) study

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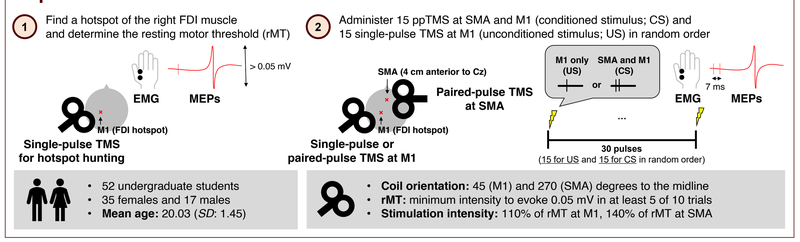
Introduction

- Experiment 1 examined connectivity between the supplementary motor area (SMA) and primary motor cortex (M1) using paired-pulse transcranial magnetic stimulation (ppTMS).
- A subsequent study examined the sensitivity of SMA-M1 connectivity to motor sequence demand (Experiment 2).
- Based on extant literature, we anticipated that (1) conditioning M1 with SMA stimulation would induce larger motor-evoked potentials (MEPs) (Arai et al., 2011, 2012; Green et al., 2018; Rurak et al., 2021) and that (2) facilitatory effect of SMA conditioning of M1 would change following exposure to greater motor sequence content (Kennerley et al., 2004; Wiestler & Diedrichsen, 2013).

Methods

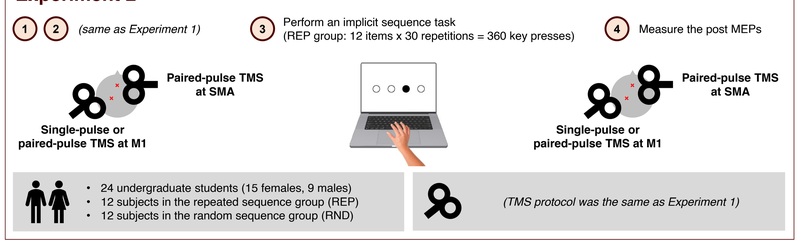
Experiment 1



- 52 undergraduate students
- 35 females and 17 males
- **Mean age:** 20.03 (*SD*: 1.45)

- **Coil orientation:** 45 (M1) and 270 (SMA) degrees to the midline
- **rMT:** minimum intensity to evoke 0.05 mV in at least 5 of 10 trials
- **Stimulation intensity:** 110% of rMT at M1, 140% of rMT at SMA

Experiment 2



- 24 undergraduate students (15 females, 9 males)
- 12 subjects in the repeated sequence group (REP)
- 12 subjects in the random sequence group (RND)

(TMS protocol was the same as Experiment 1)

Results

Experiment 1

- 34 individuals were able to receive SMA stimulation at 4 cm anterior to Cz, whereas the other 18 individuals received SMA stimulation at 5, 6, or 7 cm anterior to Cz.
- Among the 34 individuals, there was a robust facilitatory connection between the SMA and M1, manifested as a 21.22% increase in mean peak-to-peak MEPs in the CS compared to the US condition (p = .004) (**Fig. 1**).
- Facilitation was observed for 25 of 34 participants (73.53% of participants) (**Fig. 2**).
- It is worth noting that systematically moving the site of stimulation of SMA during ppTMS in an anterior fashion along the midline removed the facilitatory influence of SMA on M1 (p = .033) (**Fig. 2**).

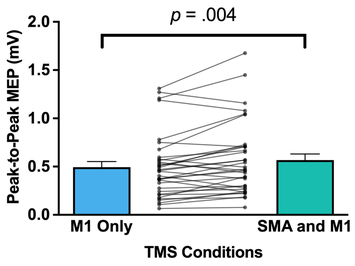


Fig. 1. MEPs of the US (M1 Only) and CS (SMA and M1) conditions. Error bars represent standard errors.

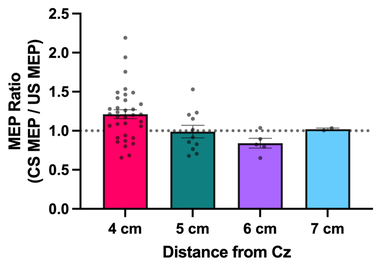


Fig. 2. CS:US MEP ratio by distance. Values greater than 1 indicate facilitation. Error bars represent standard errors.

1. The **conditioned stimulus** (SMA & M1) **induced larger MEPs** compared to the unconditioned stimulus (M1 only).

2. **MEPs of the unconditioned stimulus** (M1 only) **decreased after typing repeated sequences.**

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Results (cont.)

Experiment 2

- After performing the implicit sequence task, MEPs of the US condition decreased in the repeated sequence group (p = .037) (see REP (orange bar) in the left panel of **Fig. 3**).
- The increase in the facilitatory effect of SMA after performing the implicit sequence task was larger in the repeated sequence group (**Fig. 4**).
- At the end of the task, the response time (RT) of the repeated sequence group was faster than the RT of the random sequence group (**Fig. 5**).

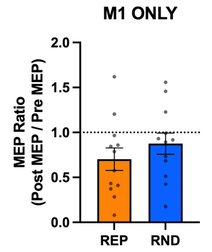

Fig. 3. Post:Pre MEP ratio. Values less than 1 indicate decreased MEPs after task. Error bars represent standard errors.

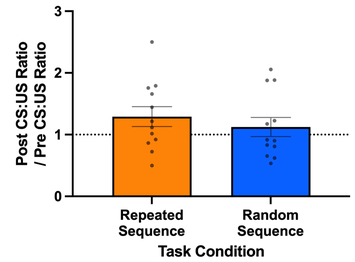

Fig. 4. Facilitatory effect ratio. Values greater than 1 indicate increased facilitatory effect after task. Error bars represent standard errors.

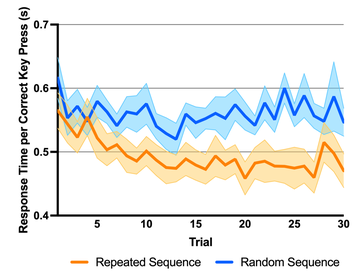

Fig. 5. Task Performance. Shaded area represents standard errors.

Discussion

- Based on the results from Experiment 1, connections from 4 cm anterior to Cz, assumed to be associated with SMA, with M1 exert a faciliatory influence on M1 excitability. While this claim is congruent with interpretation from extant literature, targeting at 4 cm is driven by coil size and may, in fact, not actually target SMA (pre or proper). This issue needs to be resolved as we move forward.
- Initial observation from Experiment 2 suggests that the faciliatory influence of SMA on M1 is increased following brief exposure to sequence knowledge (see limitations below).
- The decrease in the MEP amplitude observed in Experiment 2 may reflect an increase in the efficiency of the neural processing involved in the task, such that the same amount of motor output is achieved with less cortical activation.

Limitations

- Measurement error may have occurred when locating the site of stimulation of SMA.
- Placement of coils is limited by coil size (30 mm) and location of individual FDI hotspot.
- The sample size used in Experiment 2 is small (power < 0.8).

References

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