Is muscle co-activation preferentially driven by overlapping cortical map regions?

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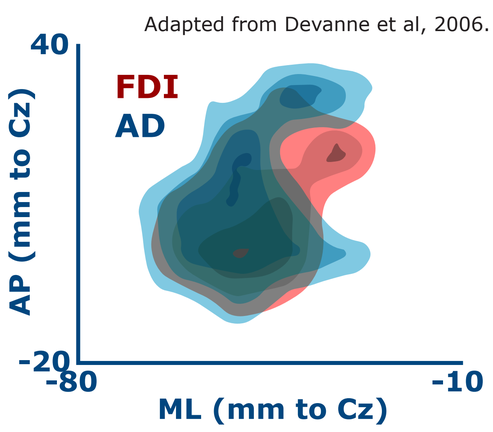
Overlapping cortical muscle maps: a substrate for synergistic activation?

Motor cortical representations of proximal and distal muscles, such as anterior deltoid (AD) and first dorsal interosseous (FDI), overlap [1, 2].



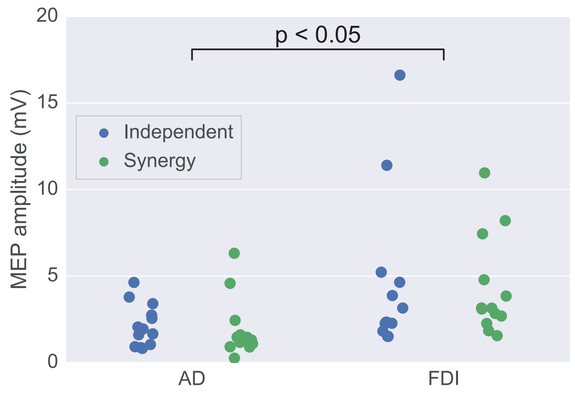
Motor evoked potential (MEP) amplitude in response to transcranial magnetic stimulation (TMS) of motor cortex.

Overlap of cortical muscle maps may facilitate synergistic co-activation of muscles. This study tests the hypothesis:
During synergistic tasks, overlapping portions of the muscle maps are preferentially activated compared to non-overlapping regions.

Participants

Participant	Age (Years)	Sex	Laterality Index (%)	AD AMT (%MSO)	FDI AMT (%MSO)
1	22	F	100	58	38
2	21	M	100	78	40
3	22	M	67	68	36
4	32	M	100	46	34
5	21	M	100	33	28
6	22	M	100	66	45
7	22	M	100	70	46
8	31	F	100	60	33
9	21	F	67	69	30
10	23	M	100	66	25
11	21	M	71	60	44
12	21	F	100	68	38
13	23	M	100	63	46
Mean	*23.2*	*69% M*	*92.7*	*61.9*	*37.2*
SD	*3.75*		*14.0*	*3.2*	*1.9*

All subjects were healthy and right-handed. As expected, active motor threshold was lower (above), and MEP amplitude was higher (below) in FDI than AD, because direct corticospinal projections innervate distal muscles more than proximal. (AMT- active motor threshold, MSO- max stimulator output.)



References

1. H. Devanne et al., The comparable size and overlapping nature of upper limb distal and proximal muscle representations in the human motor cortex. Eur. J. Neurosci. 23, 2467–2476 (2006).

2. J.-A. Rathelot, P. L. Strick, Muscle representation in the macaque motor cortex: an anatomical perspective. Proc. Natl. Acad. Sci. U. S. A. 103, 8257–8262 (2006).

3. M. van de Ruit, M. J. L. Perenboom, M. J. Grey, TMS brain mapping in less than two minutes. Brain Stimul. 8, 231–239 (2015).

4. H. Devanne, L. G. Cohen, N. Kouchtir-Devanne, C. Capaday, Integrated motor cortical control of task-related muscles during pointing in humans. J. Neurophysiol. 87, 3006–3017 (2002).

Contact information

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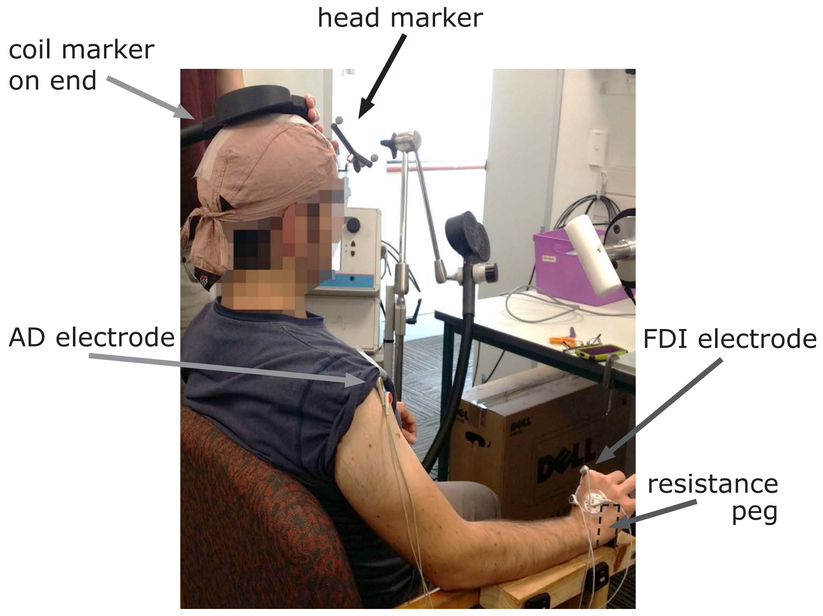
* https://github.com/mwar136/TMS-mapping-and-analysis

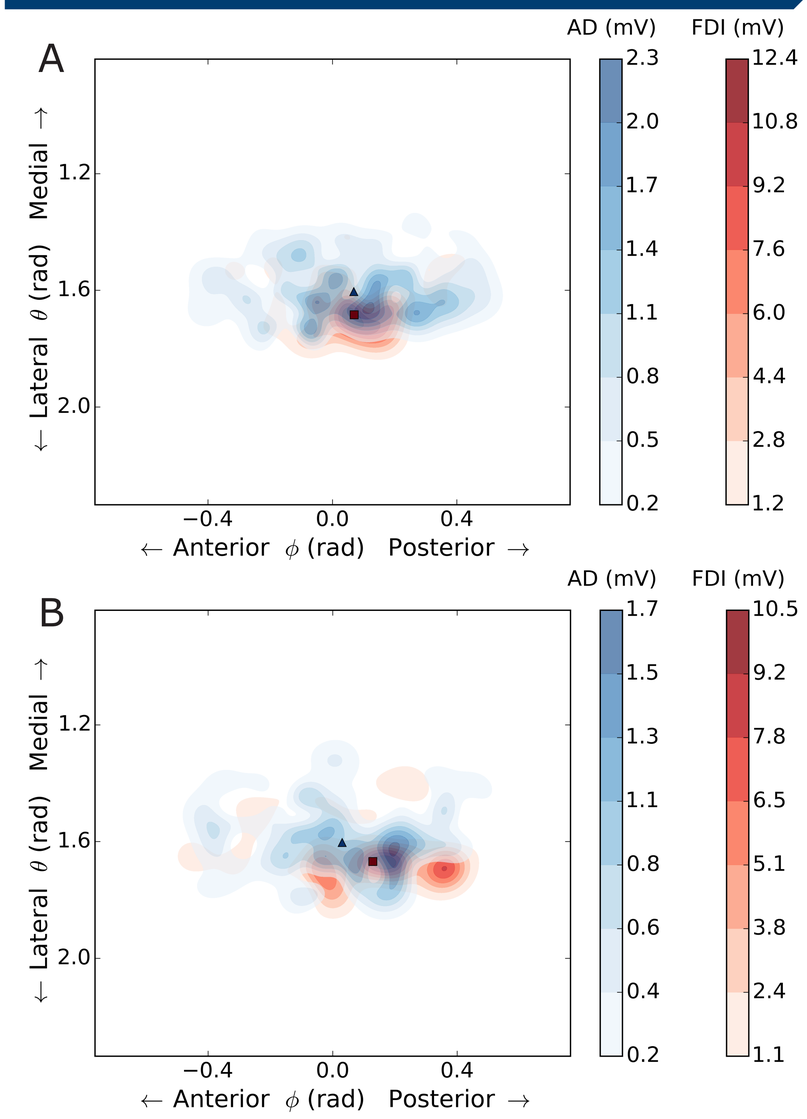
Fast, optically tracked, dual-muscle TMS mapping



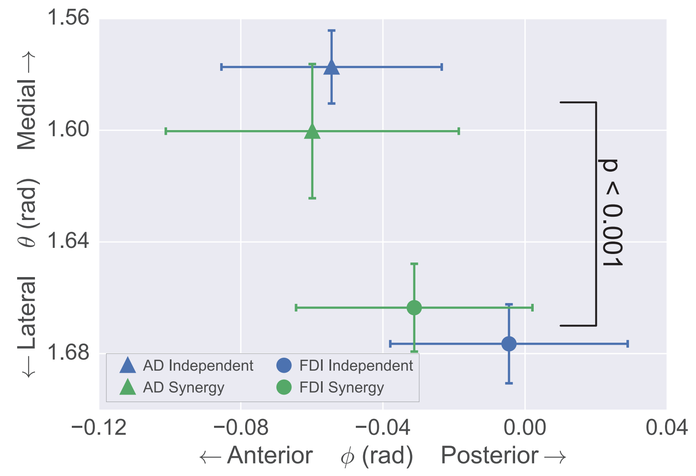
Optical tracking (Polaris, NDI) of coil and head during mapping and recording of EMG from AD and FDI.

Tasks Repetitive actions, in time with a metronome (4 - 5.5 s per stim):
1) thumb-index finger pinch; FDI map only
2) push peg with palm, from shoulder; AD map only
3) combined - pinch & push; map both muscles

FDI and AD muscle maps overlap, COGs show somatotopy

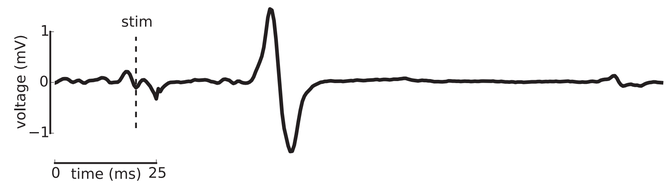


AD (blue) and FDI (red) muscle maps during independent (A) and synergy (B) movements. Maps show large overlap, particularly of highly excitable areas. Centre of gravity (COG) of FDI (red square) is lateral of AD COG (blue triangle) in both maps. Position is relative to Cz.



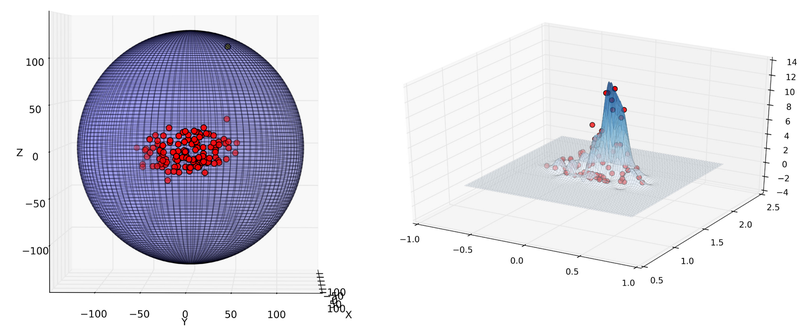
AD map COGs are medial to FDI, as expected from somatotopy, but distance between COGs does not change between tasks.

Target muscle activation level was 10±3% of RMS MVC when active and < 10 μV at rest.



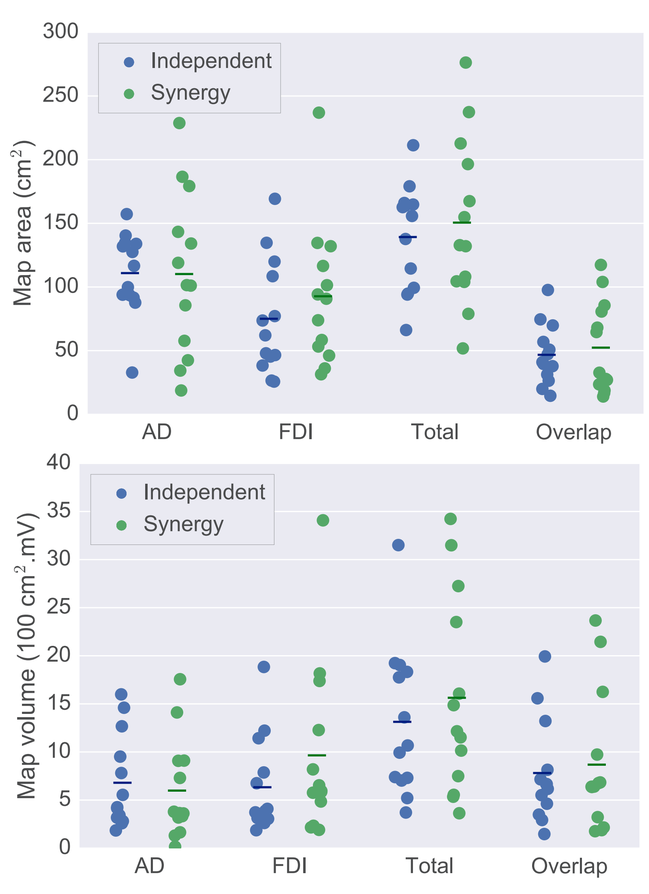
TMS Delivered at 120% active motor threshold (AMT) for each muscle. Each map used 120-150 pseudorandomly placed stimulations [3].

Data collection and analysis Coil and head 3-D positions and orientations, and MEPs, at times of TMS stimulation were saved using custom software*.



3-D stimulation locations were fitted to a sphere, then represented in 2-D spherical coordinates. The cloud of MEP values & positions was resampled onto a regular grid (MEP_{est}) using radial basis function interpolation.

Map areas and volumes do not change between tasks



Preferential activation would change the amount of overlap of muscle maps. Map areas (MEP_{est} ≥ 10% max MEP) and volumes (area × MEP amplitudes) did not change significantly between independent and synergistic tasks. % of overlap also did not change.

Discussion and future directions

1. No evidence for preferential excitation of overlapping regions of muscle maps for synergistic activation.

2. No change in overall excitability in the synergistic task suggests that FDI and AD are independent in terms of co-activation, which has implications for horizontal connectivity (excitatory or disinhibitory) between the networks associated with these muscles.

3. FDI may be 'special'; previous studies suggest coactivation of FDI and ECR is not similarly independent [4].