TMS-EEG equipment compatibility: Next-generation stimulator achieves reduced post-TMS EEG artefact recovery latency, allowing an earlier recording of clean signal.

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Introduction

Transcranial magnetic stimulation (TMS) is a non-invasive brain stimulation technique used to modulate the neuronal excitability of targeted brain areas. The TMS stimulus is an electromagnetic pulse that penetrates the scalp to reach cortical brain regions. A concurrent electroencephalogram (EEG) records the scalp electrical activity; the excitatory and inhibitory postsynaptic potentials of synchronous neurons. Performing TMS and EEG concurrently can be problematic. The electromagnetic energy generated by the TMS pulse causes nearby EEG amplifiers to become saturated (Ilmoniemi and Kičić, 2009). Consequently, an artefact obstructs the signal recording on the EEG trace after the TMS pulse. TMS evoked potentials in the first ~25ms on the EEG trace indicate the neuronal excitability of the stimulation target region. Therefore, it is desirable to reach recording range as early as possible (Huber *et al.*, 2012).

The post-TMS artefact recovers at different time durations based on TMS-EEG hardware configurations. Deymed Diagnostic have manufactured next-generation stimulators and electrodes, which are proposed to generate reduced artefact recovery latencies following TMS. The artefact recovery latencies of the pairwise conditions will be measured and compared to determine the compatibility of the current TMS-EEG system versus the new-generation TMS-EEG system.

Methods

<u>EEG signal pairwise comparison of 2 TMS stimulators and 2 EEG electrodes</u>

Deymed Diagnostic, Czechia: DuoMAG MP and DuoMAG MP-EEG stimulators and TruScan 1.0 and 2.0 electrodes, see figure 1 for conditions

<u>Setup</u>

- Phantom head stimulation was performed on a Galia melon (*Cucumis melo var. reticulatus*). Melon skin has similar impedance properties to human skin (Tidswell *et al.*, 2003).
- C3, Cz, ground and reference electrodes were applied using Spectra 360 electrode gel in 10-20 configuration. Impedance levels did not exceed 5 kΩ.
- Electrodes were connected to the 'TruScan RE - 32 channel headbox'.
- The 'DuoMAG 70 butterfly coil' (70BF) was positioned above the C3 electrode at a 45-degree angle to the mid-sagittal line. Electrode wires were taped laterally to minimise electrical interference with the coil handle (Sekiguchi *et al.*, 2011).
- Data was recorded on the EEG software 'TruScan Acquisition' (Deymed Diagnostic, Czechia).

<u>Triggering</u>

- TMS was delivered for 40 pulses at 0.25Hz.
- 70% of maximum stimulator output.

Conditions	Variable 1	Variable 2	
	DuoMAG Stimulator Type	TruScan Electrodes 1.0	TruScan Electrodes 2.0
1-Black	DuoMAG MP	✓	
2- Magenta	DuoMAG MP-EEG	✓	
3- Cyan	DuoMAG MP		✓
4 - Blue	DuoMAG MP-EEG		✓

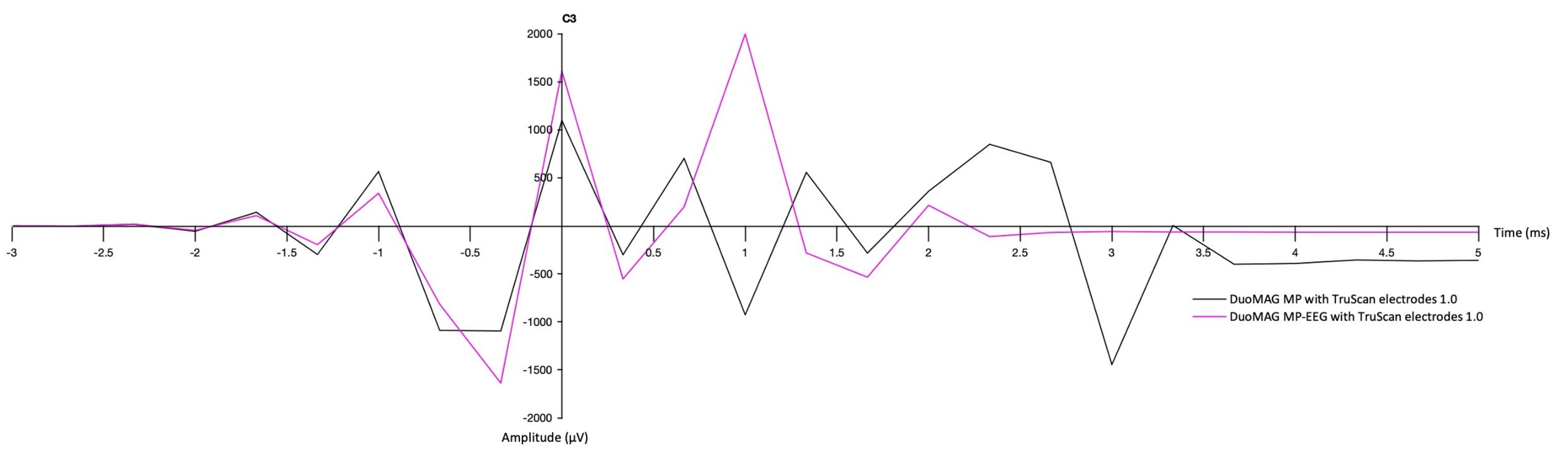
<u>Figure 1.</u> The hardware combinations used in the four pairwise comparison conditions.

<u>EEG data analysis</u>

- Data analysis was conducted using the 'ERPLAB' toolbox in 'EEGLAB', MATLAB R2022a (MathWorks, United States).
- EEG signals were epoched between -1000ms and 1000ms of the TMS pulse at 0ms. Epochs from the 40 pulses were averaged into one trace per condition. Traces from four trial replicates were merged to produce the graphs.
- 50Hz line noise was removed by a notch filter between 48-52Hz.
- Baseline correction was conducted using data from -500 to -110ms prior to stimulation (Rogasch *et al.*, 2013).
- The amplitude(µV) rate of change between time points was calculated. Artefact recovery latency was noted as the time (ms) that the amplitude recording was sustained at less than 5% different to the previous recording.
- Non-parametric Kruskal-Wallis test (≤ 0.05) was performed on SPSS Statistics 28.0.1.1 (IBM, Unites States).

Results. Variable 1: Monophasic stimulator

1. The artefact recovery latency for the DuoMAG MP-EEG stimulator was significantly shorter than for the DuoMAG MP stimulator using TruScan electrodes 1.0.



<u>Figure 2.</u> The DuoMAG MP-EEG stimulator post-TMS artefact recovers to a baseline an average of 1.3ms faster than the DuoMAG MP stimulator with TruScan electrodes 1.0, a significant difference in latencies with a *p* value of 0.009.

Using the TruScan electrodes 2.0, an insignificant average reduction of 0.7ms in artefact recovery latency was observed using the DuoMAG MP-EEG stimulator compared to the DuoMAG MP stimulator.

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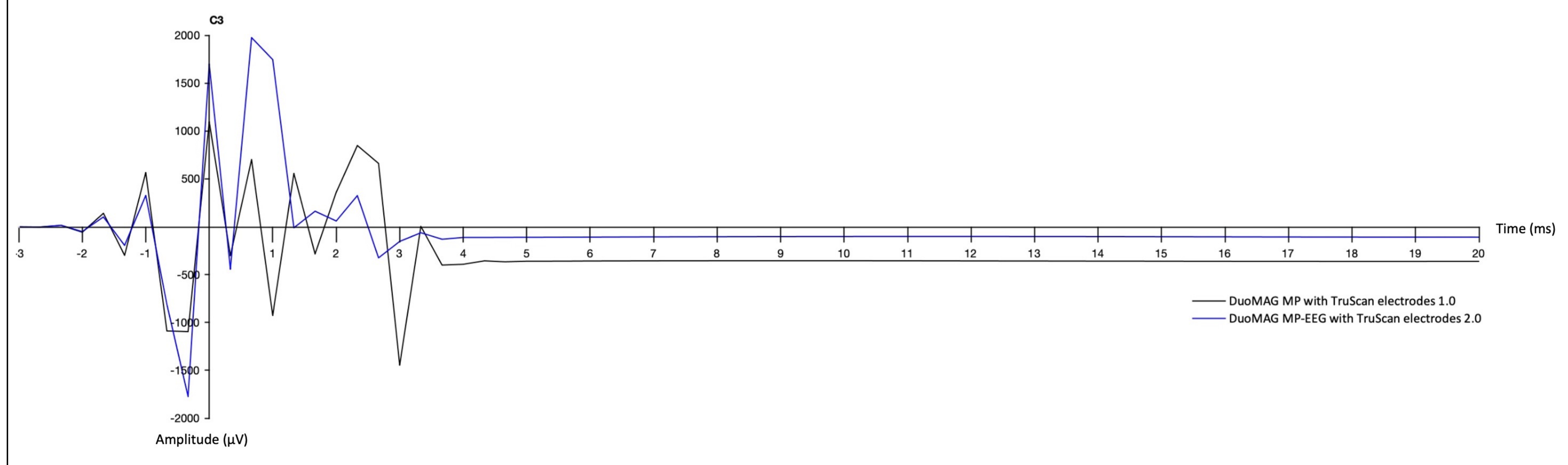
2. The next-generation TMS-EEG system generates a reduced artefact recovery latency and an improved return to baseline compared to the current TMS-EEG system.

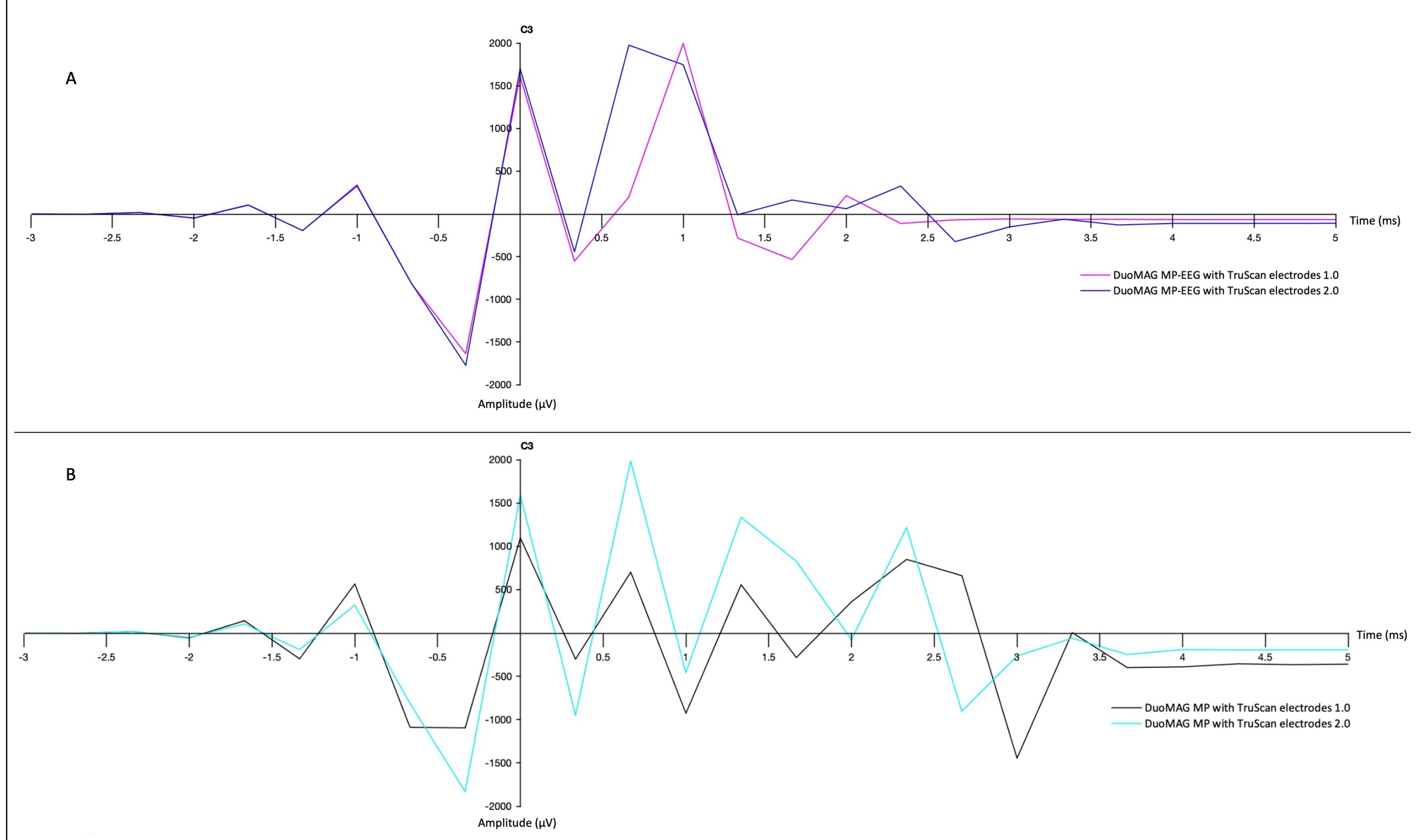


<u>Figure 3.</u> Administering TMS using next-generation models DuoMAG MP-EEG stimulator and TruScan electrodes 2.0 generated an artefact on average 1.3ms shorter than the artefact generated by the DuoMAG MP stimulator and Truscan electrodes 1.0. The respective average artefact recovery latencies of 3ms and 4.1ms were statistically different (*p* = 0.023).

The EEG signals stabilised at different offsets to the baseline at 5ms. The DuoMAG MP stimulator signal stabilised at -360µV, 250µV further from the baseline measurement than the DuoMAG MP-EEG stimulator. The monophasic pulse width was reduced from 1ms+ to ~500µs in the DuoMAG MP-EEG next-generation stimulator, causing the signal to stabilize at -110µV.

Results. Variable 2: Electrodes

3. The artefact recovery latencies were not significantly different between using TruScan electrodes 1.0 and 2.0 in both stimulation conditions.



<u>Figure 4.</u> Compared to the current electrodes, the next-generation electrodes generated artefacts on average 0.4ms shorter using the DuoMAG MP stimulator but 0.2ms longer using the DuoMAG MP-EEG stimulator to administer TMS. The changes in artefact latencies were insignificant.

The structure of the TruScan electrodes 1.0 were improved by adding resistors to the TruScan electrodes 2.0. The resistors aim to minimise eddy currents by reducing current-loop areas (Ilmoniemi and Kičić, 2009).

Conclusions

1. The DuoMAG MP-EEG stimulator is more compatible with the TruScan electrodes 1.0 and 2.0 than the DuoMAG MP stimulator.
2. There is no difference in the compatibility of using TruScan electrodes 1.0 and 2.0 with both models of DuoMAG MP stimulators.
3. Upgrading equipment to the next-generation Deymed Diagnostic TMS-EEG system will reduce the artefact recovery latency compared to the current system.

References

Huber, R. *et al.* (2012) 'Human Cortical Excitability Increases with Time Awake', Cerebral Cortex, 23(2), pp.1-7. doi: 10.1093/cercor/bhs014

Ilmoniemi, R. and Kičić, D. (2009) 'Methodology or Combined TMS and EEG', Brain Topography, 22(4), pp.233-248. doi: 10.1007/s10548-009-0123-4.

Rogasch, N. C. *et al.* (2013) 'Short-Latency Artifacts Associated with Concurrent TMS-EEG', Brain Stimulation, 6(6), pp. 868-876. doi: 10.1016/j.brs.2013.04.004

Sekiguchi, H. *et al.* (2011) 'TMS-induced artefacts on EEG can be reduced by rearrangement of the electrode's lead wire before recording', Clinical Neurophysiology, 122(5), pp.984-990. doi: 10.1016/j.clinph.2010.09.004.

Tidswell A.T. *et al.* (2003) 'A comparison of headnet electrode arrays for electrical impedance tomography of the human head', Physiol Meas, 24, pp.527-544. doi: 10.1088/0967-3334/24/2/36.