Timing is Everything: event-related TDCS improves context-dependent motor adaptation

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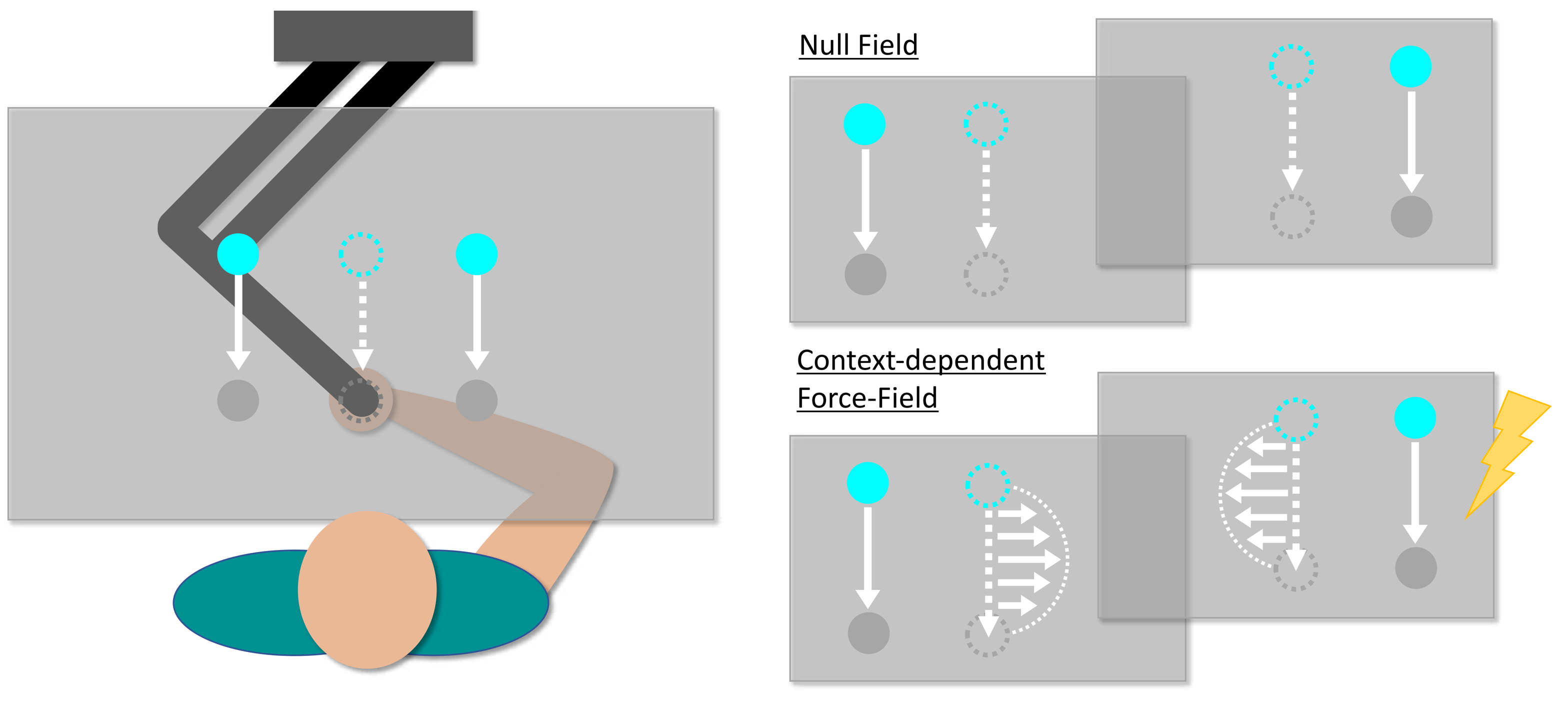
Background & Aims

- Most theories of motor learning are based upon coincident, time-dependent mechanisms of plasticity.
- However, when investigating motor learning & rehabilitation using TDCS, the temporal parameters of stimulation are particularly non-specific.
- Typically, 15-20 minutes of stimulation is applied during, and/or prior to, a behavioural task. During this time a number of different behaviours can be performed, not just the behaviour of interest.
- Despite this, research has shown that TDCS can have relatively immediate effects on neural excitability & firing patterns, even after very short periods of stimulation [1, 2].
- We therefore aimed to design a more temporally precise TDCS protocol, whereby event-related TDCS (er-TDCS) is delivered in short 'bursts' during specific movements throughout a motor learning task.

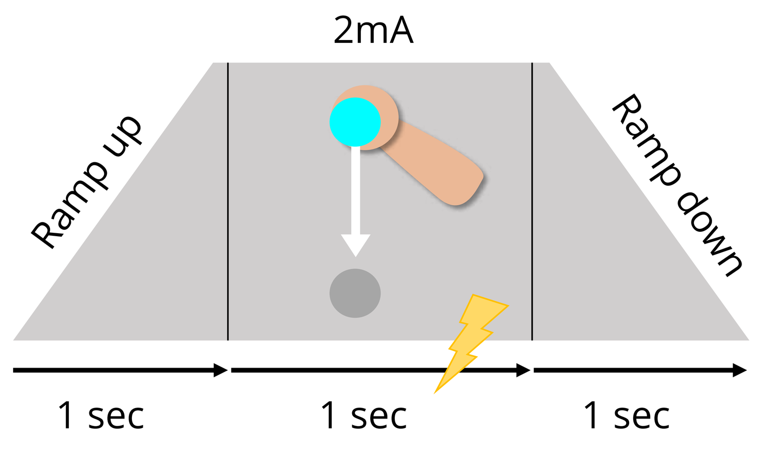
Materials & Methods



Left) A schematic of the task set up. Movements were always made in the midline position, but the cursor & target position would be shifted either 10cm to the left or right. ***Right)*** Examples of the task display during null & force-field trials. er-TDCS was applied during the adaptation phase & only on trials with a right-shift in display & CCW force-field

- 60 healthy young adults were pseudo-randomly assigned into either an M1, Cerebellar or Sham stimulation group (n = 20 per group).
- Participants were required to make out-to-in reaching movements during a context-dependent motor adaptation task, where either a clockwise (CW) or counterclockwise (CCW) force-field was applied to their movements [3].
- The CW & CCW fields were always associated with a 10cm leftward & rightward shift in the visual display of the cursor & target respectively, while movements remained in the midline position – creating two distinct learning contexts.

- er-TDCS was only applied to movements made during trials with a CCW force-field & associated rightward shift in task display.
- For the M1 & Cerebellar groups, 2mA of anodal TDCS was applied for 1 second, starting at movement onset which was ramped up/down over 1 second during a hold period between trials & a passive return to the home position.
- Sham stimulation was held at 2mA for 10 secs at the start of the adaptation phase, with 10 second ramping periods.



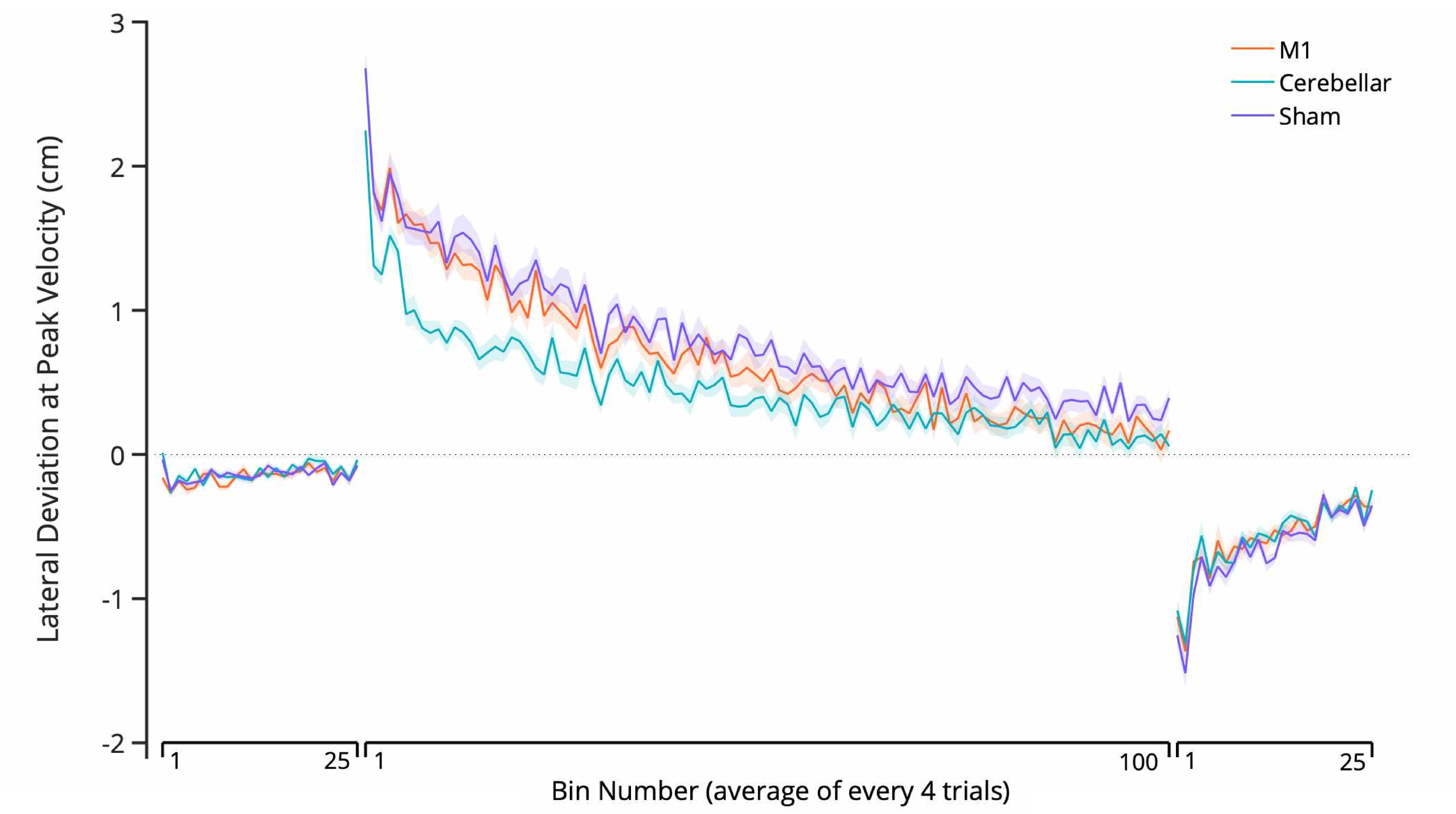
Above) A schematic representation of er-TDCS protocol. 1 second of stimulation was applied during specific reaching movements, with 1 second ramping periods pre/post. ***Right)*** A time course of the study protocol.

Baseline
100 Trials, Null-Field, No Stimulation

Adaptation
400 Trials, Context-Dependent Force-Field, er-TDCS

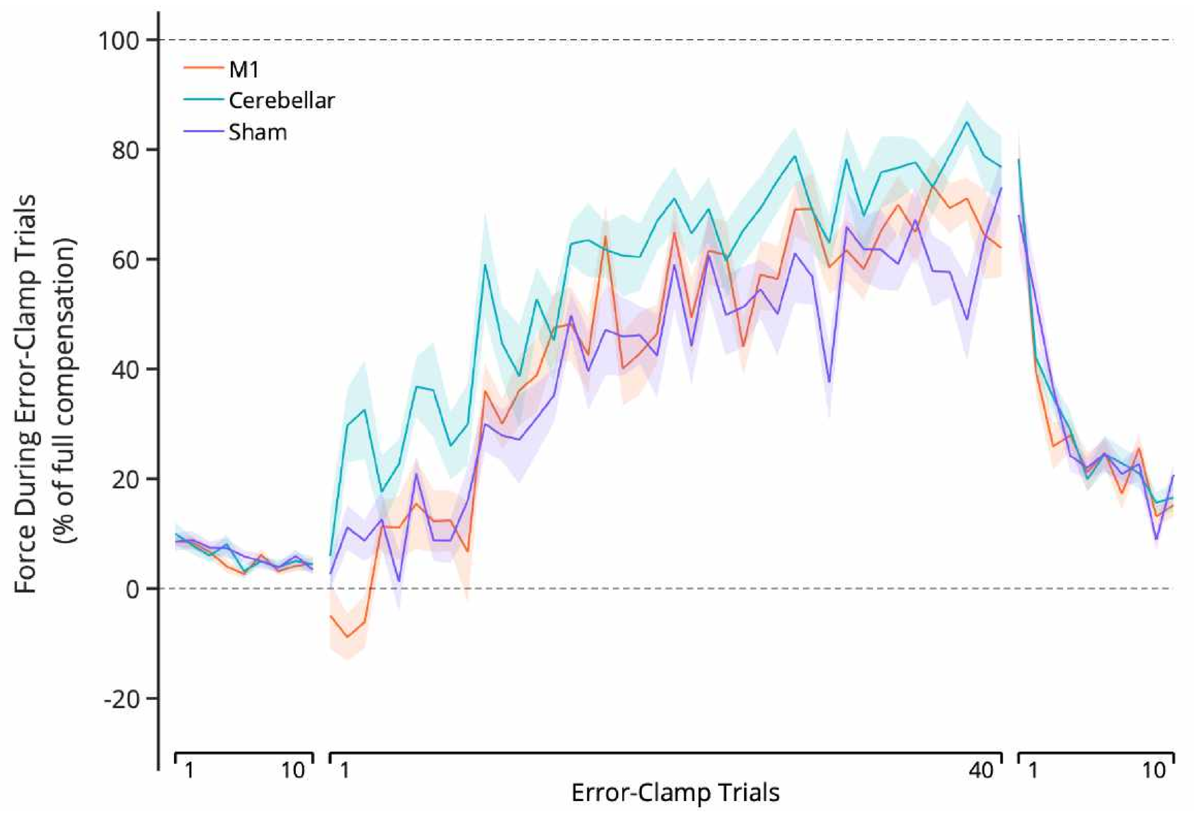
Washout
100 Trials, Null-Field, No Stimulation

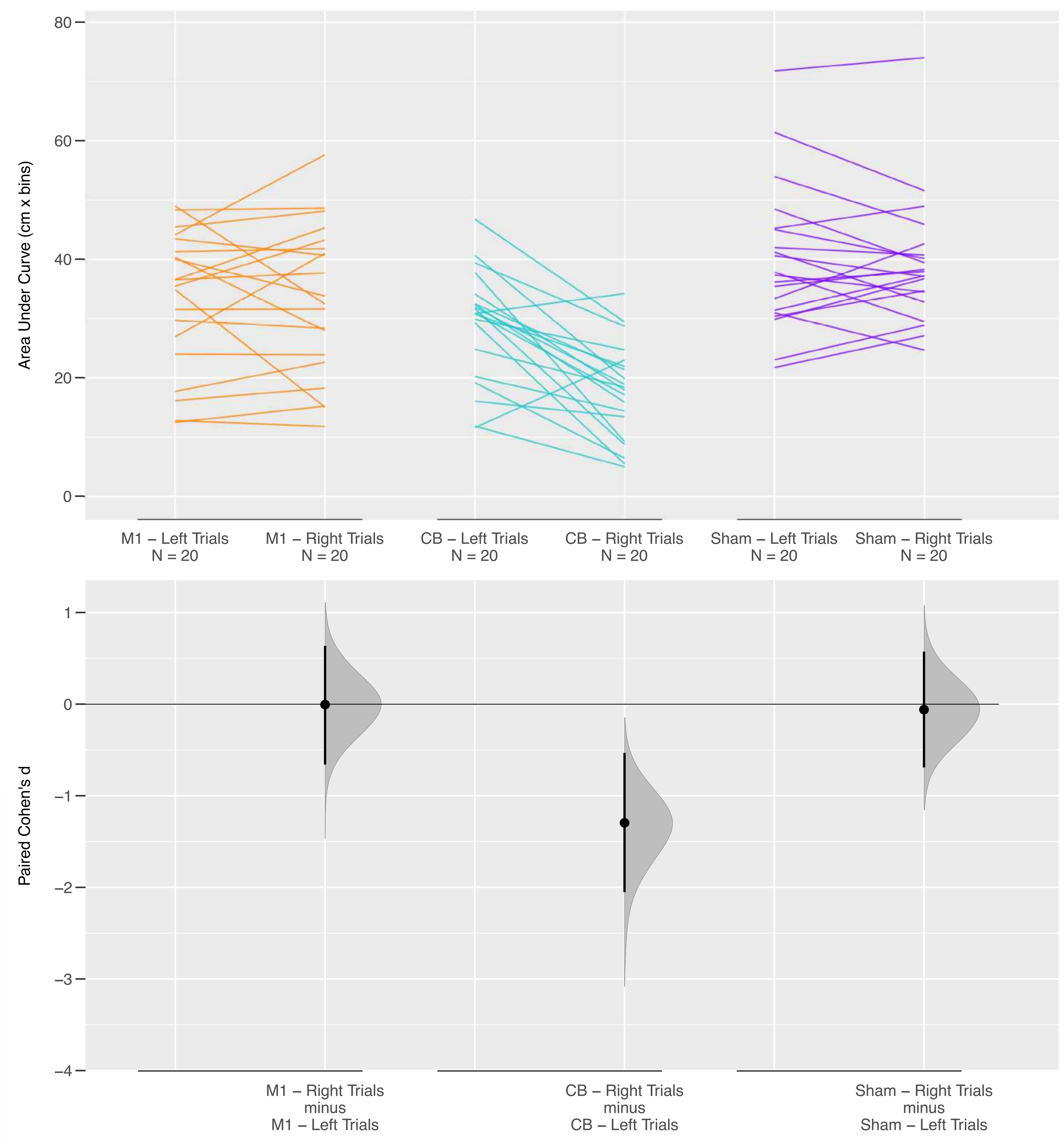
Results



Above) Mean lateral deviation (± SE, shaded region), averaged every four trials into bins for each stimulation group. During the first 25 bins of trials (baseline) participants made reaching movements towards the target in a null field. The adaptation phase immediately followed (next 100 bins of trials), during which CW & CCW force-fields were imposed. The final 25 bins of trials (washout) were again performed in a null field. Lateral deviation has been sign adjusted in order to depict adaptation to both CW & CCW fields combined.

Left) Average force compensation during error-clamp trials (± SE, shaded region) in each task phase for all three stimulation groups. Data is sign adjusted to show the percentage of full compensation for both left & right-shift error-clamp trials. 60 error-clamp trials (10%) were distributed proportionally throughout the task in order to measure the predictive compensatory forces applied against a virtual channel wall.





Comparisons of error (area under the curve) made during left & right-shift trials in the adaptation phase are displayed above in a Cumming estimation plot. Area under the curve error for each participant in each group is plotted on the upper axes, with each paired data connected by a line indicating the difference in adaptation performance between the two trial contexts. The corresponding paired Cohen's d is plotted on the lower axes as a bootstrap sampling distribution. Mean differences are depicted as dots, with 95.0% CIs indicated by vertical error bars.

Conclusions

Event-related stimulation of the cerebellum improved overall force-field adaptation, which was selectively driven by a reduction of error during stimulated compared to unstimulated trials.

- This result provides initial behavioural evidence that brief periods of TDCS can modulate motor learning, when applied coincidentally with movements during a motor adaptation task.
  - We propose the temporal coupling between stimulation epochs & movement during the task is important & acts on Hebbian-like plasticity to improve learning.
  - Although it is difficult to isolate the exact mechanism responsible for the specific improvement in performance following er-TDCS, it seems likely to be mediated by enhanced time-dependent mechanisms of plasticity (e.g. long term depression) occurring in the cerebellum.
- This study highlights new ways in which TDCS may be utilized in research & rehabilitation, with focus on increased temporal specificity.

brainbox initiative

[1] Bindman, L. J., Lippold, O. C. J., & Redfearn, J. W. T. (1964). The Journal of physiology, 172(3), 369. **[2]** Nitsche, M. A., & Paulus, W. (2000). The Journal of physiology, 527(Pt 3), 633. **[3]** Howard, I. S., Wolpert, D. M., & Franklin, D. W. (2013). Journal of neurophysiology, 109(10), 2632-2644.