Influence of visual motion characteristics on corticospinal excitability during target interception

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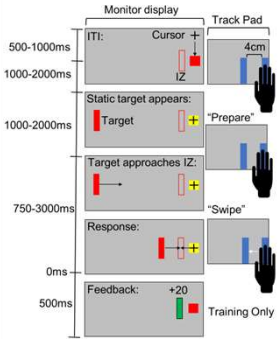
INTRODUCTION

- Intercepting moving targets relies on internal estimates of a target's visual motion properties, such as target speed, spatial distance, and duration[2].
- Evidence from non-human primates has revealed that activity within the primary motor cortex (M1) is sensitive to both time-varying aspects of a visual target's motion and to motor planning[3].
- These findings suggest that M1 utilizes sensory information to help guide the preparation of interceptive responses[4]; however, it remains unclear how this information is integrated in M1 to facilitate accurate performance.
- Here, we applied single-pulse transcranial magnetic stimulation (TMS) over M1 to investigate the influence of target motion parameters on human corticospinal excitability (CSE) while preparing to intercept a moving target.

How do target speed, motion duration, and distance influence the modulation of M1 excitability?

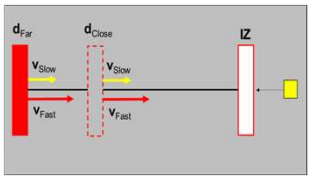
METHOD

Interception Task



- Participants (N = 12, 8M, 23.1±3.6) used a trackpad to make swiping movements with their right index finger.
- On each trial, participants abducted their finger to intercept a target moving horizontally at a constant velocity toward a fixed interception zone (IZ).
- Feedback during training provided information about spatial error relative to the ideal interception point.
- Surface electromyography (EMG) electrodes were placed over the right first dorsal interossei (FDI) and abductor digit minimi (ADM) muscles.

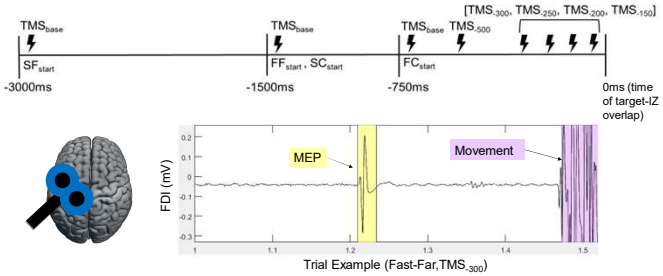
Task Conditions



Condition	Velocity (cm/s)	Distance (cm)	Duration (ms)
Fast-Close (FC)	24	18	750
Fast-Far (FF)	24	36	1500
Slow-Close (SC)	12	18	1500
Slow-Far (SF)	12	36	3000

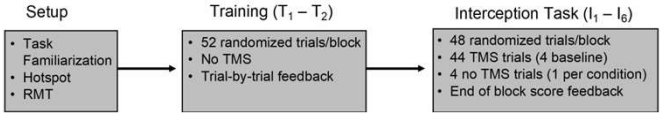
- The target appeared after a variable delay at one of two distinct distances (Close/Far) and approached the IZ at one of two velocities (Slow/Fast).
- Motion duration was matched in the Fast-Far and Slow-Close conditions, allowing us to isolate the effects of target kinematics, independent of preparation time.

Transcranial Magnetic Stimulation



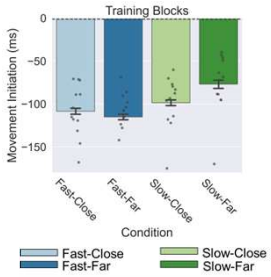
- Left M1 FDI hotspot and resting motor threshold (mean RMT = 45.3 ± 6.8) were established at the start of each session.
- Motor-evoked potentials (MEPs) in response to TMS were elicited from the right FDI muscle using a stimulation intensity of 115% RMT at stimulus onset (TMS_{base}) or at one of five different latencies relative to the time the target reached the interception zone [TMS_{-500}, TMS_{-300}, TMS_{-250}, TMS_{-200}, TMS_{-150}].
- Movement initiation (EMG onset) and MEP amplitude were analyzed using the VETA toolbox[7].

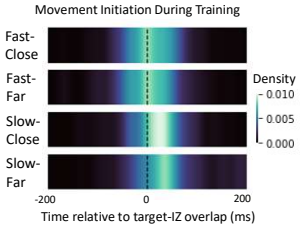
Experimental Design



RESULTS

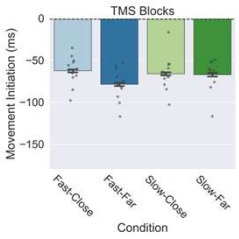
Target velocity, but not distance, influences response initiation

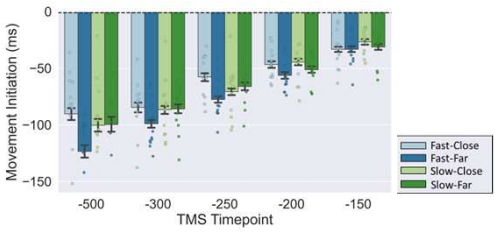




- Movement initiation (EMG onset relative to target-IZ overlap) occurred earlier for fast target trials (p =0.043).
- No effect of target distance on movement initiation (p = 0.666).

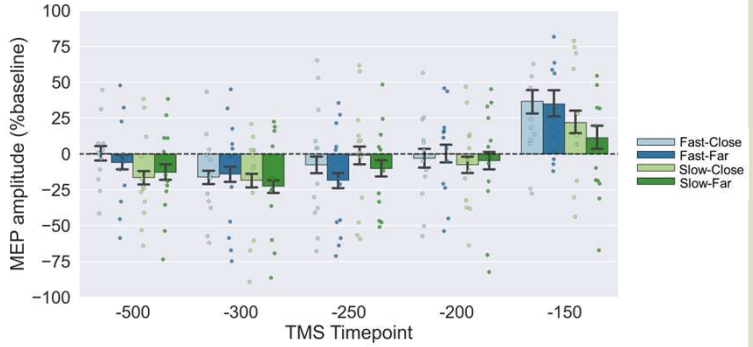
TMS at late stages of preparation delays movement initiation





- Movements were initiated later when TMS stimulation was elicited closer to target arrival (p =0.001).
- Significant effect of target distance (p =0.019) but not velocity (p =0.198).

Higher target velocities are associated with more CSE facilitation



- MEPs were normalized for each participant relative to their average MEP_{base}.
- There was a significant effect of stimulation timepoint on MEP amplitude (p =0.001): suppression was observed early in the interception preparation period, followed by facilitation when TMS was applied ~150 ms before the target reached the IZ.
- MEPs tended to exhibit less suppression and greater facilitation for faster moving targets (p =0.07).
- There was no significant effect of target distance (p =0.324).

DISCUSSION

- In this study we examined how visual motion properties influence the modulation of corticospinal excitability when preparing to intercept a moving target.
- Consistent with previous behavioral findings, movement initiation occurred sooner for higher target speeds and was delayed if TMS was administered closer to the time of target interception.
- Similar to the dynamic pattern of suppression and facilitation observed in delayed-response tasks[5], MEPs were reduced relative to baseline at earlier TMS time points and increased closer to movement initiation.
- Faster moving targets resulted in relatively less early suppression (-300 ms) and greater late facilitation (-150 ms), which may underlie earlier movement initiation.
- Altogether, these results suggest M1 excitability is shaped by relevant visual motion properties for action specification during interception.

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