Non-specific impact of Transcranial Magnetic Stimulation sound patterns on cortical oscillations and visual detection

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BACKGROUND

Transcranial Magnetic Stimulation (TMS) is a method of non-invasive brain stimulation widely used in fundamental research studies to causally modulate brain activity and cognitive functions. However, simultaneously with the brief electromagnetic field delivered to the cortex, each TMS pulse generates a brief but intense clicking sound. In order to cancel the influence of this auditory stimulation, experimental designs contrast active stimulation with a sham TMS condition that mimics the auditory stimulation associated with TMS. However, very few studies have studied the specific impact of such auditory stimulation on task performance[1].

Crossmodal sensory interactions are ubiquitous in the brain[2]. In the domain of visuo-spatial attention and perception, in particular, sounds delivered shortly prior or simultaneously to the onset of a visual stimulus have been shown to modulate visual detection performances[3]. Additionally, auditory stimulation can phase-reset cortical oscillations in the auditory but also visual cortex[4] and, lastly, a large literature has shown that trains of clicking sounds can entrain cortical oscillations following the frequency of the auditory train through a phenomenon called Auditory Steady-State Response (ASSR)[5]. Collecting more knowledge about the effects of auditory stimulation during task performance is crucial to better judge if sham TMS constitutes a good control condition for the sensory side effects of TMS.

GOALS

- Characterize the impact the auditory stimulation associated to sham TMS on brain activity and behavioral performance.
- Investigate if such impact may interact with the effects of active TMS pulses.

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4. Romei et al., 2012, *Current Biology.*
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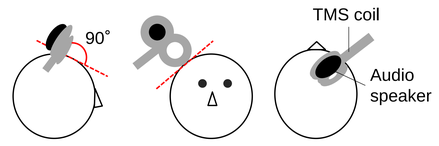
METHODS

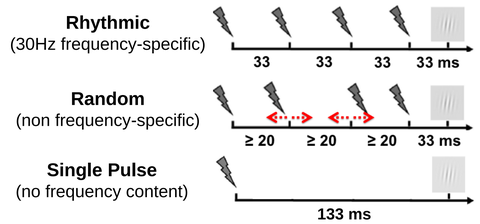
Recordings done on 11 healthy right-handed subjects.

Position of Sham TMS coil



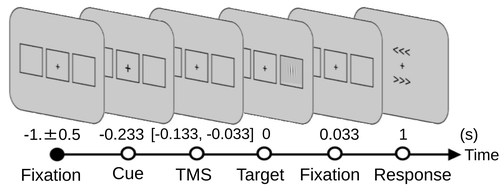
Placed in a frontal right location, above electrode FC2 on EEG array.

Sham TMS patterns



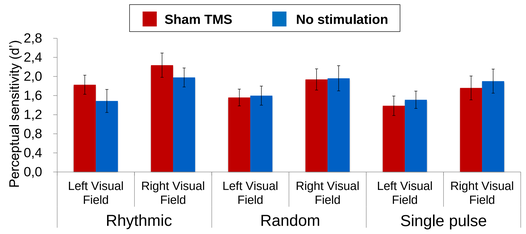
Each pattern is tested in different blocks with **sham TMS** trials and **no stimulation** trials randomly interleaved in each block.

Conscious visual detection at 50% visibility threshold

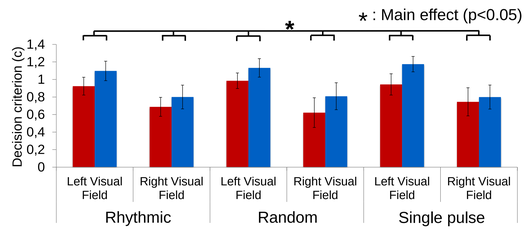


Each trial could be: Left Target /Right Target /No target
Participants had 3 possible answers : Left /Right /Not seen

BEHAVIORAL RESULTS



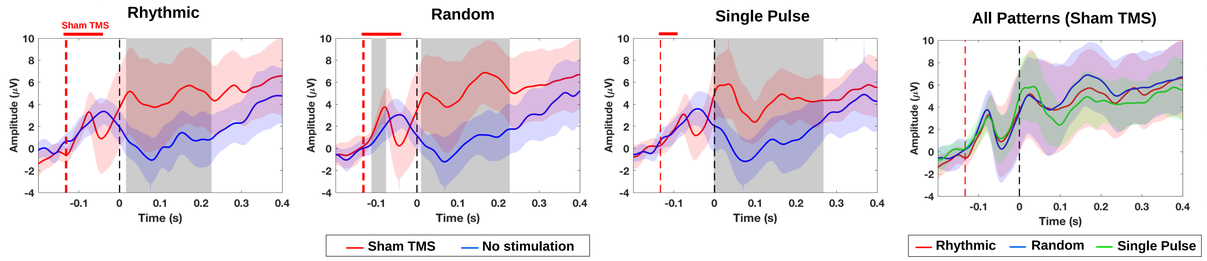
‣Pre-target auditory stimulation did not modulate the perception of the visual target.



‣However, pre-target auditory stimulation modulated subjective perceptual decision-making processes

EEG RESULTS

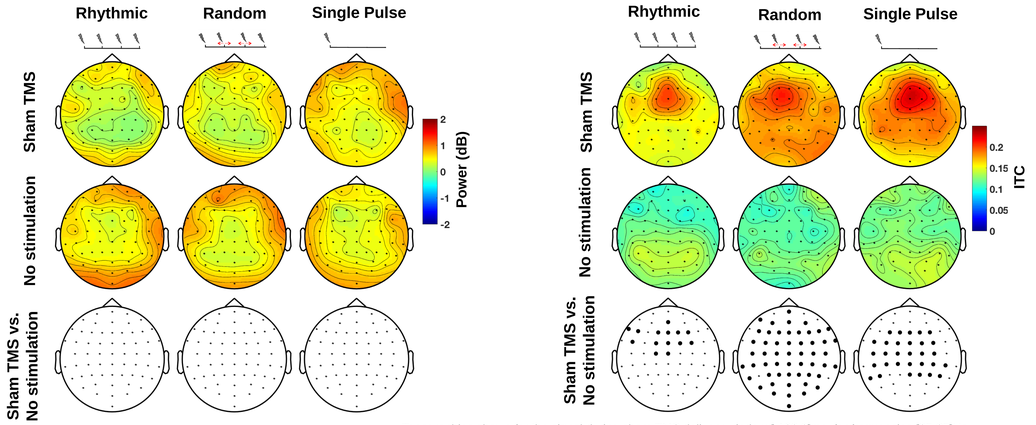
1. Auditory Event-Related Potentials



‣Sham TMS elicited clear auditory ERPs (at Cz).

‣The shape of the ERPs did not differ between sham TMS patterns

2. Entrainement of high-beta oscillations during 30Hz rhythmic sham TMS

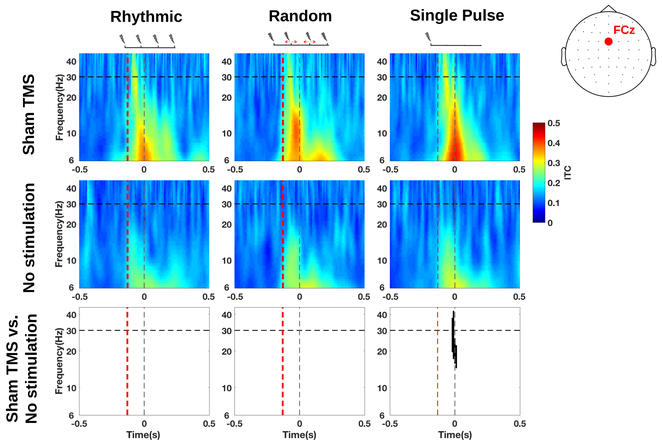


Topographies shown for the signal during sham TMS delivery window [-133 0]ms, for frequencies [25-35]Hz.
Blank topographies show statistical results, bolded electrodes reached significance (p<0.025).

‣Rhythmic sham TMS did not increase oscillation power at the frequency contained in the burst.

‣Sham TMS phase-locked oscillations in the high-beta band but this effect was not specific to rhythmic sham TMS, instead it was stronger for single sham pulses.

4. Oscillatory phase-locking in response to auditory stimulation



Time-frequency analyses for electrode FCz (in which high-beta ITC was the strongest).
Visual target onset marked as time 0. Last row shows statistical results.

‣Single Sham TMS pulses phase-locked oscillations in a broad frequency band.

CONCLUSIONS

- Pre-target rhythmic sham TMS did not entrain cortical oscillations at the frequency present in the clicking train
- Auditory stimulation
  - Crossmodally modulated perceptual decision-making processes
  - Phase-locked cortical oscillations

The absence of sham TMS-driven oscillatory entrainment strengthens the use of sham control designs in active TMS entrainment experiments. Moreover, we bring evidence that sham TMS does not induce states of neural activity (namely increased fronto-parietal high-beta oscillatory activity) that have been reported elsewhere[6,7] to contribute to the facilitation of visual perception.

Nonetheless, the non-specific effects of auditory stimulation on perceptual decision-making processes and oscillatory phase-locking that we report call for new studies to allow a better understanding of the effects of sham TMS on the brain.

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