Cerebellum and semantic memory: a TMS study with the DRM task

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Introduction

It has been proposed that memory is not actually a memory system, but rather a predictive system[1]. This view accounts for the "errors" that memory makes under normal conditions and for the adaptive value of processes such as transformation, reconsolidation and updating[2]. In the last decades, it has been shown that the cerebellum is involved in a wide range of motor and non-motor functions linked to predictive processes[3]. Neurostimulation studies reported cerebellar involvement in semantic domains, such as semantic prediction[4], semantic priming[5] and semantic memory[6], but more researches are needed to clarify cerebellar involvement in this domain.

Methods

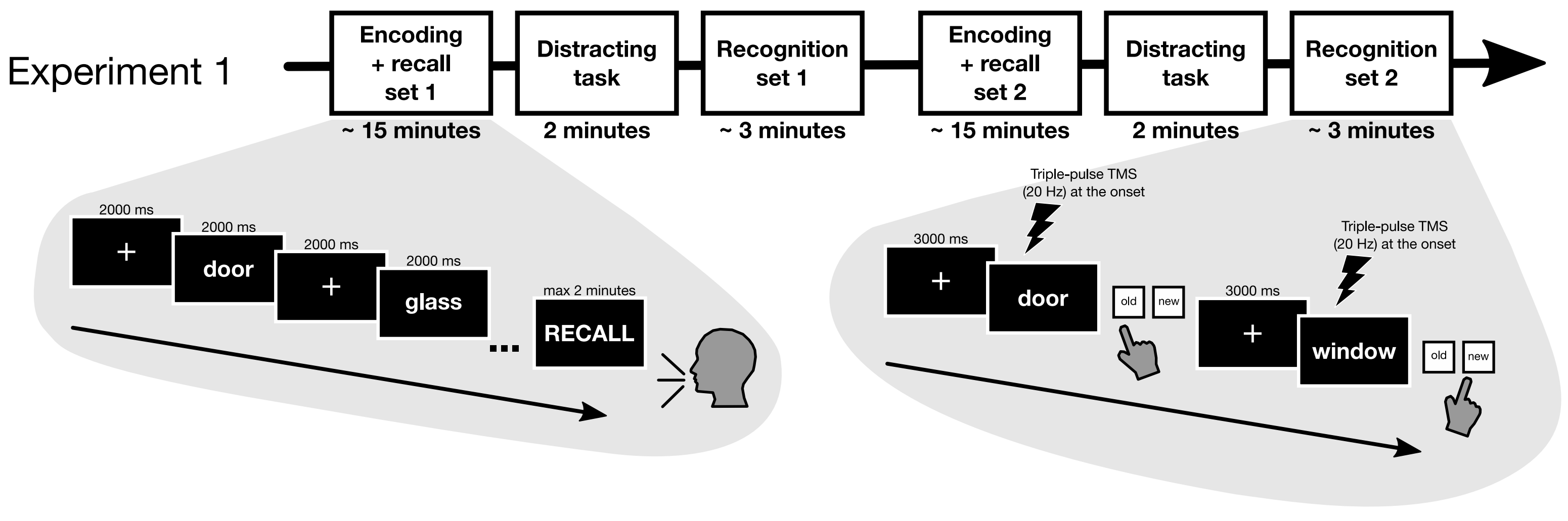
Participants

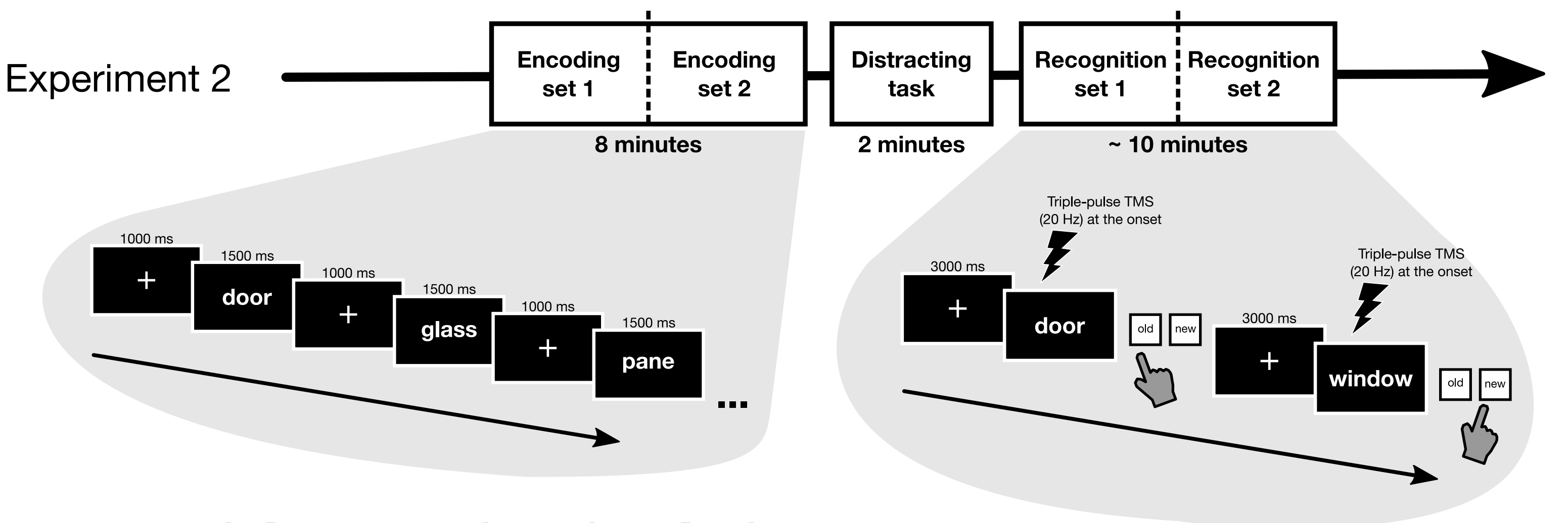
Exp 1: **24** participants (6 M, mean age = 22.7 years, SD = 2.3).
Exp 2: **32** participants (7 M, mean age = 21.6 years, SD = 1.3).

DRM task[7]

Encoding task: 8 lists related to a non-showed lure per session (15 words per list in Exp 1, 12 words in Exp 2).

Recognition task:
- Exp 1: 24 studied words, 16 unrelated, 8 critical lures per session;
- Exp 2: 32 studied words, 16 unrelated, 16 weakly related, 8 critical lures per session.

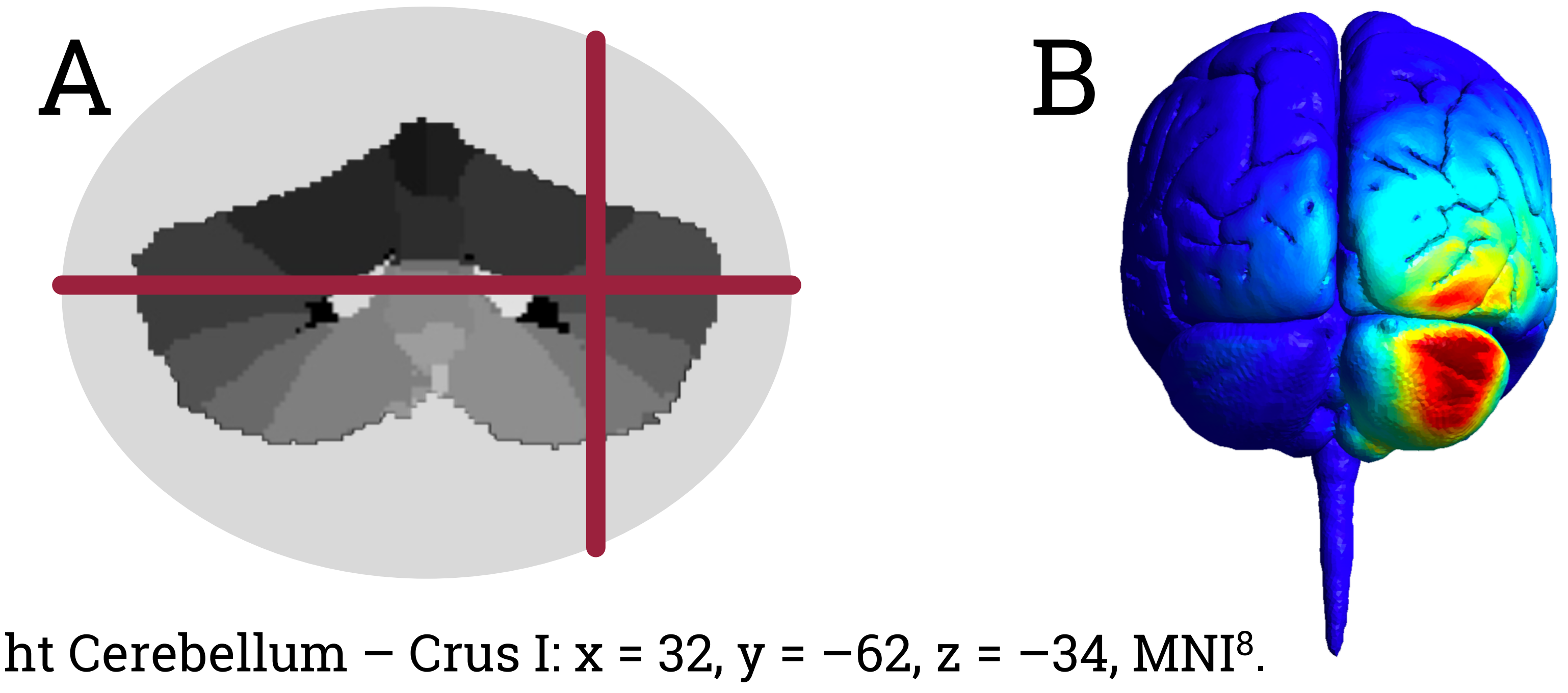




Transcranial Magnetic Stimulation

Triple-pulse 20 Hz TMS was delivered at the onset of each word during the recognition phase.

TMS over the right cerebellum or over the vertex (within participants design).



Right Cerebellum – Crus I: x = 32, y = −62, z = −34, MNI[8].

A) Localization of the anatomical coordinates for the right cerebellum; image obtained using FLS[9] and the probabilistic atlas of cerebellar lobules.

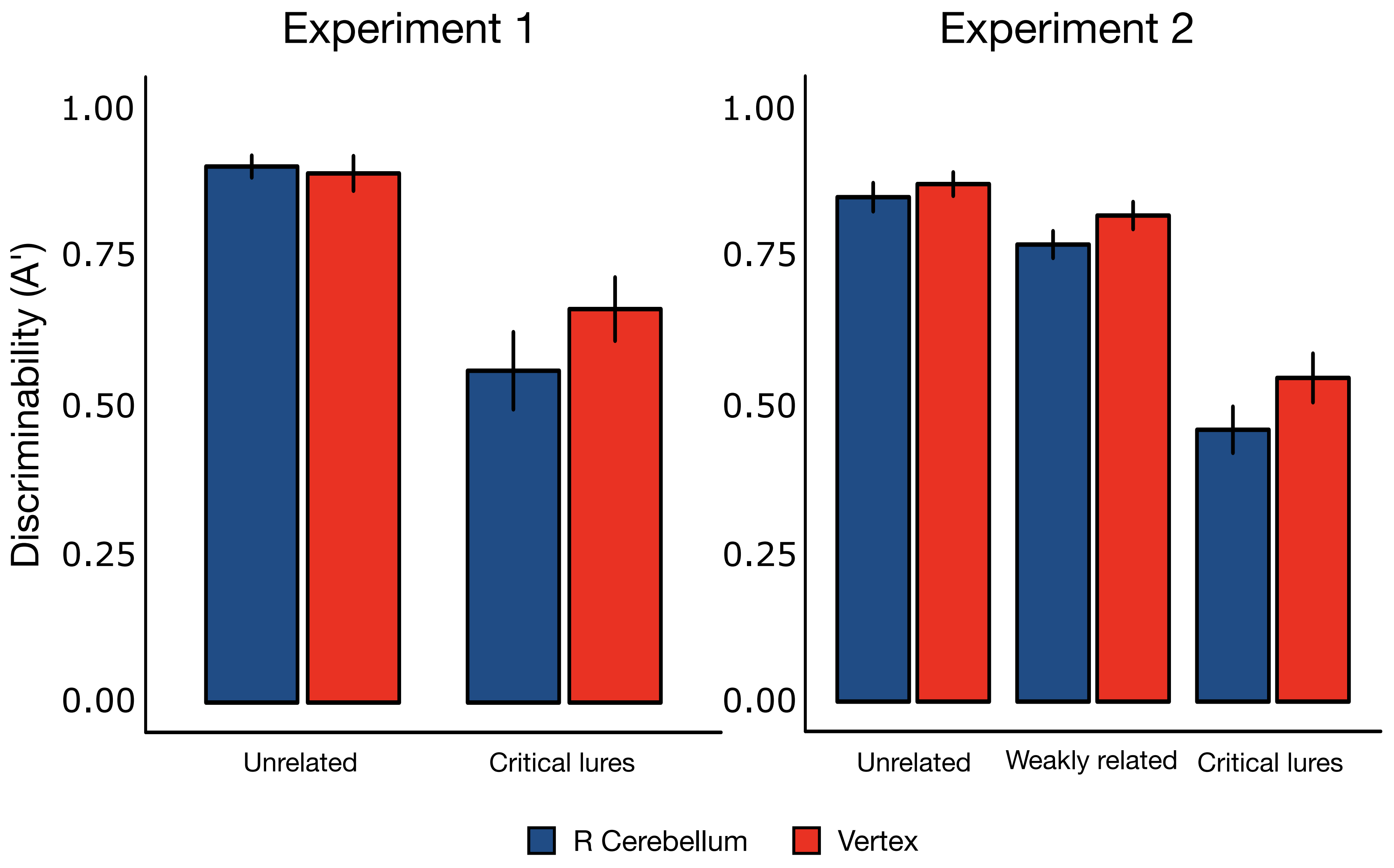
B) Model of the electric field induced by TMS during cerebellar stimulation; image obtained using simNIBS[10].

Results

We calculated detection discriminability values (A')[11] using hits as signal and the different type of new item as noise. A' provides a value comprised between 0 and 1, with values around 0.5 indicating chance performance and values around 1 good memory performance.

Exp 1: significant interaction TMS * Item, $p < .01$, $\eta p^2 = .30$. Cerebellar TMS affected participants' discriminability for critical lures compared to vertex stimulation, $p < .001$, $d = .78$; no differences were found for unrelated words, $p = .67$, $d = .08$.

Exp 2: significant main effect of TMS, $p = .01$, $\eta p^2 = .19$. Cerebellar TMS affected participants' discriminability compared to vertex stimulation. By looking at the effect sizes of the direct pairwise comparisons we can detect that cerebellar TMS compared to vertex stimulation affected more participants' discriminability for critical lures, $d = .58$, than for weakly related lures, $d = .32$, or for unrelated words, $d = .14$.



Discussion

TMS over the right cerebellum affected participants' memory performance. The disruptive effect of cerebellar TMS was present in both Experiment 1 and in its replication with a more complex task (Experiment 2). Our results are consistent with previous evidence about cerebellar participation in semantic memory[12-13] as well with more recent hypotheses about memory and prediction[2].

Previous neuroimaging studies showed that the right cerebellum is involved in the search of responses in semantic memory, while left prefrontal cortex is involved in the process of selection of responses[13]. The impaired memory performance observed here would reflect a disruption of the search in semantic memory.

Results are also consistent with previous brain stimulation and neuroimaging studies[4-6] and with established theories such as the HERA model[14].

The production of false memories has been explained using the fuzzy-trace theory[15] (FTT) or the activation-monitoring framework[16] (AMF). Within the FTT results would reflect a gist trace impairment, while within the AMF results would reflect a source-monitoring impairment.

In conclusion, results support the hypothesis of cerebellar involvement in semantic memory, thus suggesting common neural substrates for memory and prediction

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