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The posterior cerebellum supports explicit sequence learning linked to trait attribution

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Introduction

Recent research has indicated that the cerebellum is responsible for social judgments such as making trait attributions. Recent studies demonstrated that the core function of the cerebellum is to identify and reconstruct the correct sequence of a series of action events (Cattaneo et al., 2012; Christensen et al., 2014; Leggio et al., 2008). However, the role of the cerebellum in the learning and automatization of action sequences involving social mentalizing (e.g., traits) remains elusive. Moreover, how do metacognitions develop on action sequences as well as on traits implied by these actions?

This study aims to investigate whether the cerebellum supports learning of action sequences linked to trait judgment and whether the cerebellum supports metacognitive confidence in retrieving the action sequence.

Methods

Subjects. 25 healthy participants were recruited to take part in an fMRI study. We developed a memory paradigm to investigate the learning and retrieval of the temporal order of social sequences (**Fig. 1**).

Task. Participants had to learn the correct sequence of six sentences varying in duration (20 sec vs. 40 sec) and domain (social vs. non-social). After presenting the social (trait-implying) / non-social sentences, participants had to infer a common trait of the person / characteristic of the object. They then had to retrieve the sequences in an immediate memory task and provide confidence ratings about their answer.

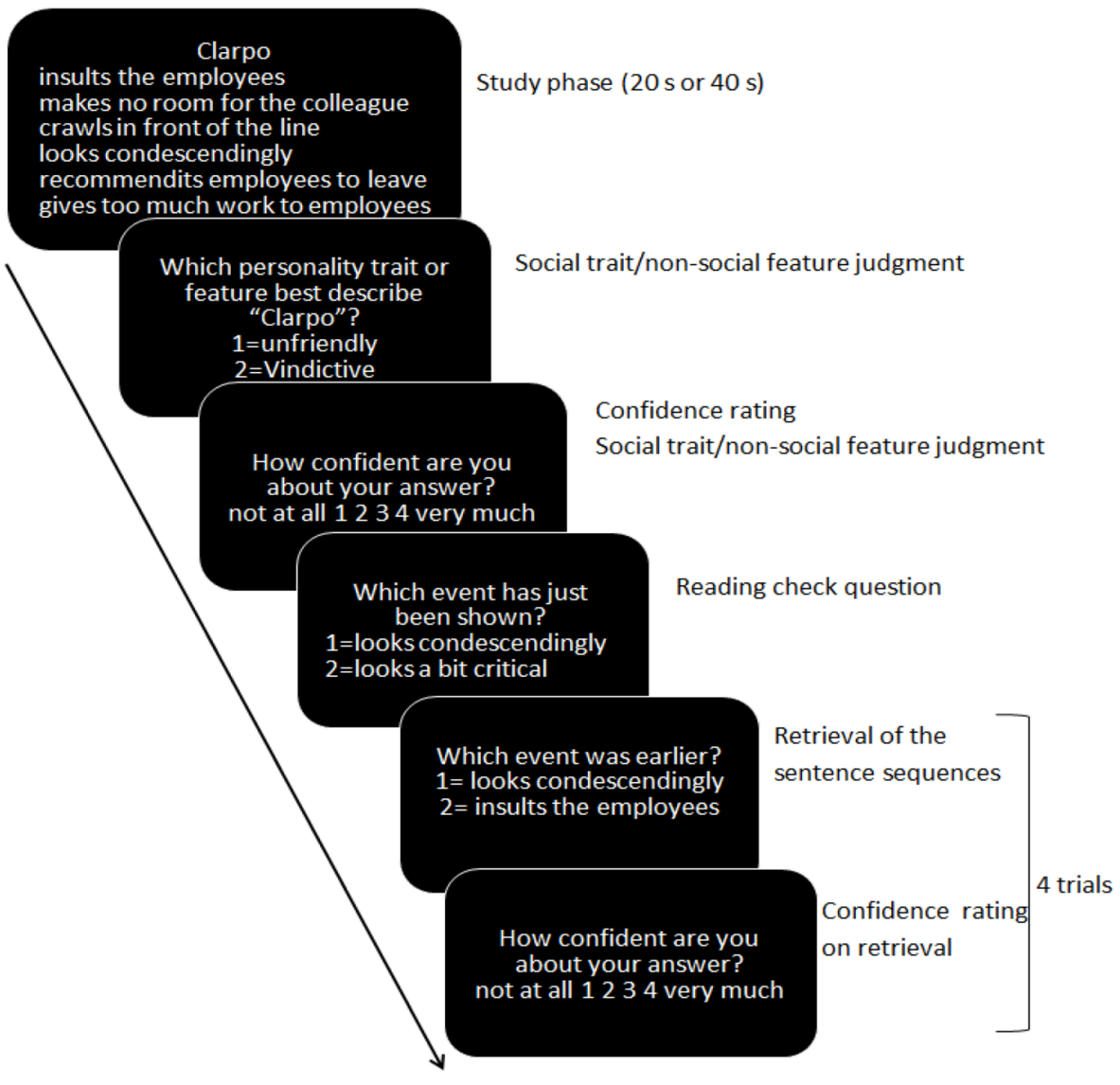

Figure 1: Experimental procedure

Analysis. At the first level, the event-related design was modeled with one regressor for each condition. Onsets were specified at the presentation of the sentence set, as well as at the presentation of each question (trait, trait confidence, retrieval, retrieval confidence).

fMRI Results

Explicit sequence learning

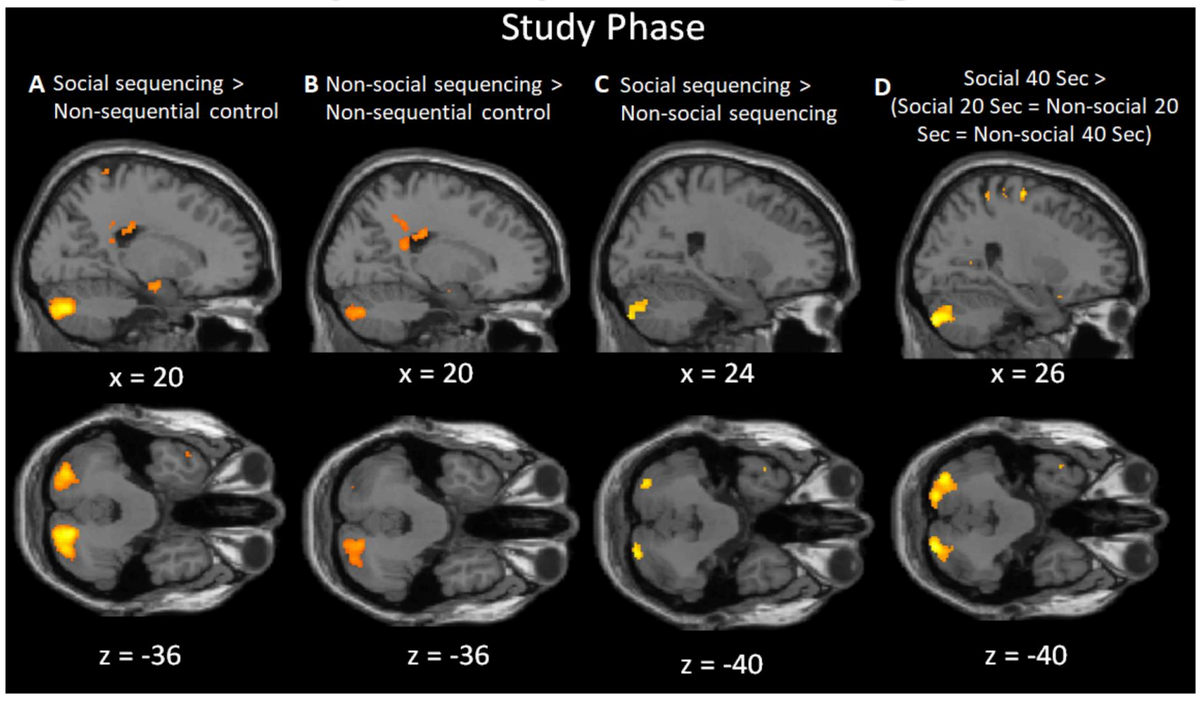

Figure 2. Contrasts while learning the sequence of trait-implying sentences at $p < 0.001$ (cluster peaks $p < 0.05$, *FWE*).

Brain activation in the posterior cerebellum (Crus II) shows more activation during trait-implying social sequencing > non-sequential control (A), non-social sequencing > non-sequential (B), social > non-social sequencing (C) and interaction with duration (D).

Meta-cognitive confidence on retrieving sequences

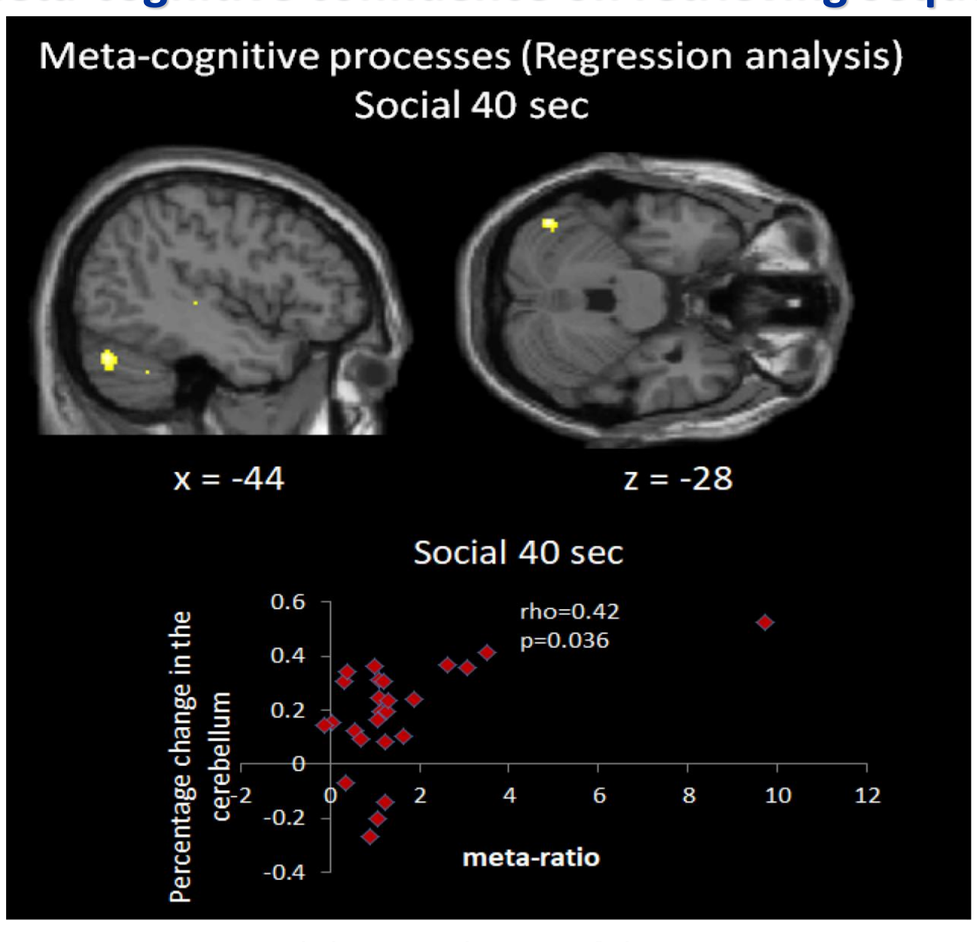

Figure 3. Contrasts while providing confidence ratings on retrieval of trait-implying sequences at $p < 0.001$ (cluster peaks $p < 0.05$, *FWE*). Meta-ratio measure for longer social 40 sec condition shows covariation with the posterior cerebellum (Crus I) in regression analysis (top) and is illustrated by a positive correlation with % signal change in the cerebellum (bottom).

Conclusion

Traits require high-level mentalizing that reflects another person's permanent internal state abstracted from behavioral descriptions. The present study shows that the posterior cerebellum is robustly engaged when the sequential order of trait-implying actions is learned. The posterior cerebellum is also involved during judgments on one's metacognitive confidence on memory of the sequences.

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