The posterior cerebellum supports Implicit sequence learning in social context

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Introduction

Learning regularities in a social environment can facilitate understanding of social behavior and interactions with other people. In dynamic social interactions, people have to update their representations of other's mental states continually. In order to investigate whether people could learn sequences of others' mental states in an implicit manner, we created a new sequencing task, combining elements from serial reaction time tasks (Nissen & Bullemer, 1987) and false belief tasks (Wimmer & Perner, 1983). To solve this belief SRT task, participants must understand that the protagonists hold mental beliefs about reality that the protagonists can see (true beliefs) or about reality that the protagonists saw earlier (false beliefs). Unbeknownst to the participants, fixed sequences of true and false beliefs by protagonists were embedded and repeated in the task.

Methods and Hypotheses

18 participants performed the implicit belief SRT task in the scanner (**Figure 1**). On each trial, four little smurfs on the top of the screen gave one or two flowers to one of two protagonists (Papa Smurf or Smurfette) at the bottom of the screen. On true belief trials, the protagonist could see the flowers. On false belief trials, the protagonist's face was turned away, and therefore could not see any changes. During training, the hidden sequence was fixed, while during test, the hidden sequence was randomized in some blocks, either totally (**TR**) or only the true-false belief orientations (**RO**). In a control group, the task was structurally similar but non-social (Go/No-Go task, n = 20)

<u>Hypothesis:</u>

The posterior cerebellum will be activated more during

(1) training when the new belief sequence is learned > test
(2) test when the belief order is randomized > fixed order

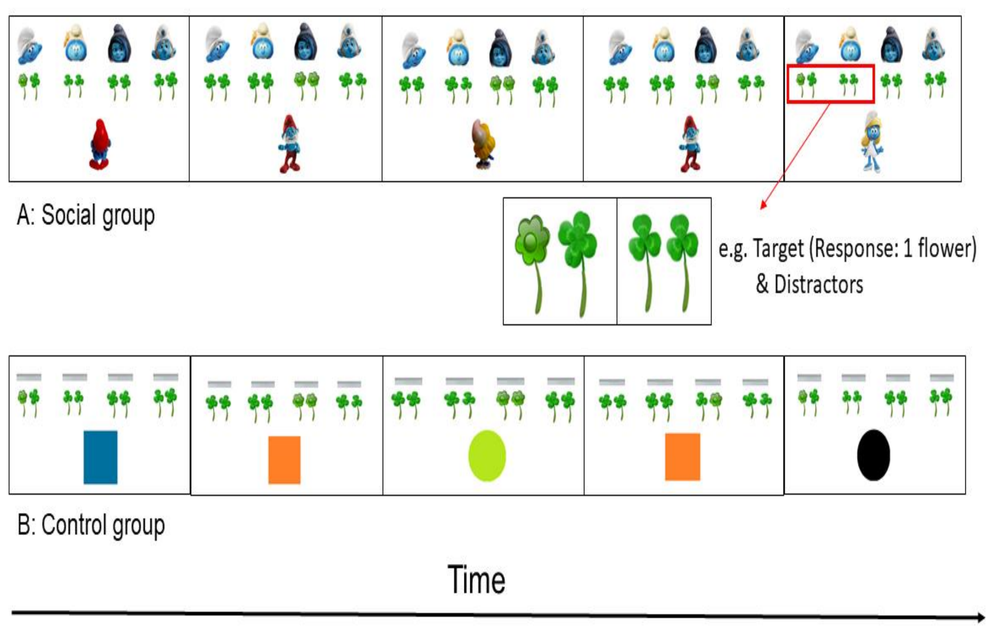

Figure 1: An example of implicit mentalizing sequence learning. The correct response : on true/go trials: report the number seen; on false/no-go trials: report the number seen earlier by the protagonist/same shapes).

Results

<u>Behavioral Results:</u>

(1) Increasingly faster RTs across the training phase (**Figure 2A**).
(2) Slower RTs when detecting violations during the test phase (**2B**). This effect was stronger in the Social than Control group (**2C**).

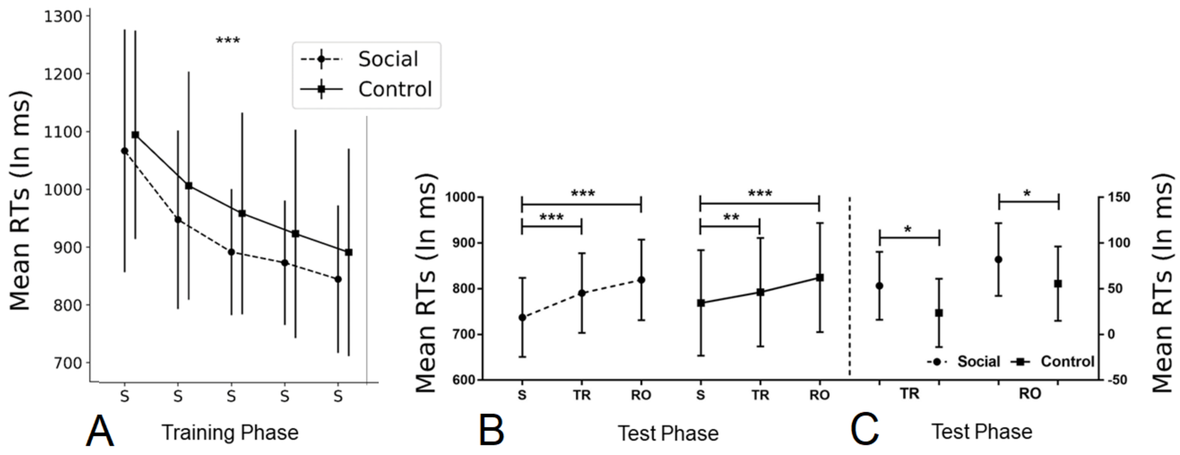

Figure 2: Implicit social sequence learning. **A:** Mean RTs in each block. **B**: Detecting violations at the test phase. **C:** Mean RTs differences (Random minus Sequence) in detecting violations in Social and Control groups.
S: Sequence blocks; **TR**: Total Random blocks; **RO**: Random Orientation blocks

<u>Neuroimaging Results:</u>

The posterior cerebellum (Crus I & II) was more activated

(1) during Sequence blocks in Training phase > Test phase,
(2) during Random belief blocks > Sequence blocks (**Figure 3**).

…and this more in Social > Control groups (**Figure 4**).

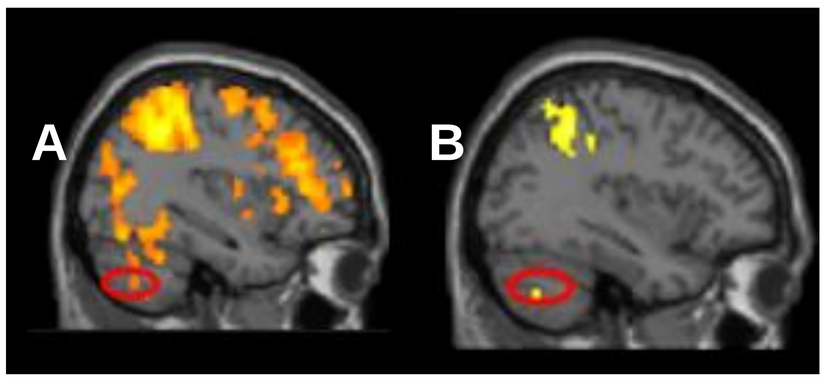

Figure 3: The posterior cerebellum was significantly activated in **A:** learning a new belief sequence (-34, -64, -44, Crus II). **B:** in detecting sequence violations (-36, -64, -42, Crus I)

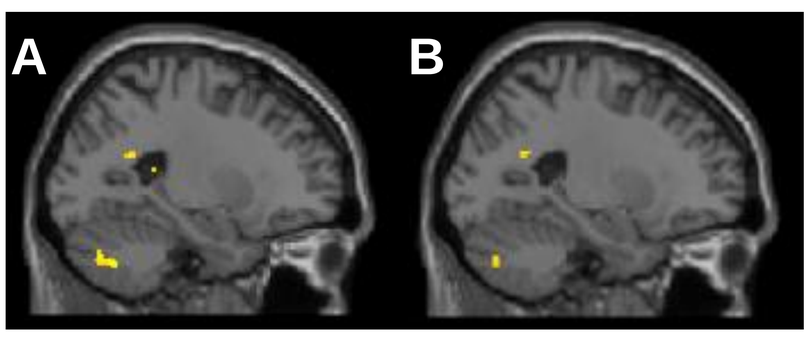

Figure 4: The posterior cerebellum was significantly more activated in the Social group compared to Control group in **A:** Sequence maintenance (-22, -68, -38, Crus II) **B:** Detecting sequence violations (-26, -74, -36, Crus II)

Conclusion

The posterior cerebellum (Crus II & I) is preferentially engaged in implicit belief sequence learning. Hence, it is a domain-specific area for processing sequences involving mentalizing

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