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Neural Geometry of Abstract Working Memory

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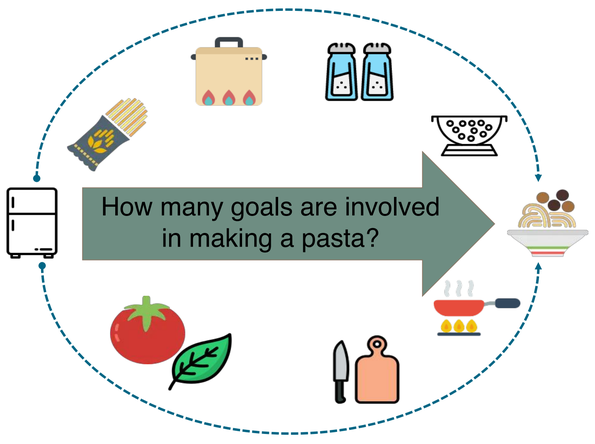
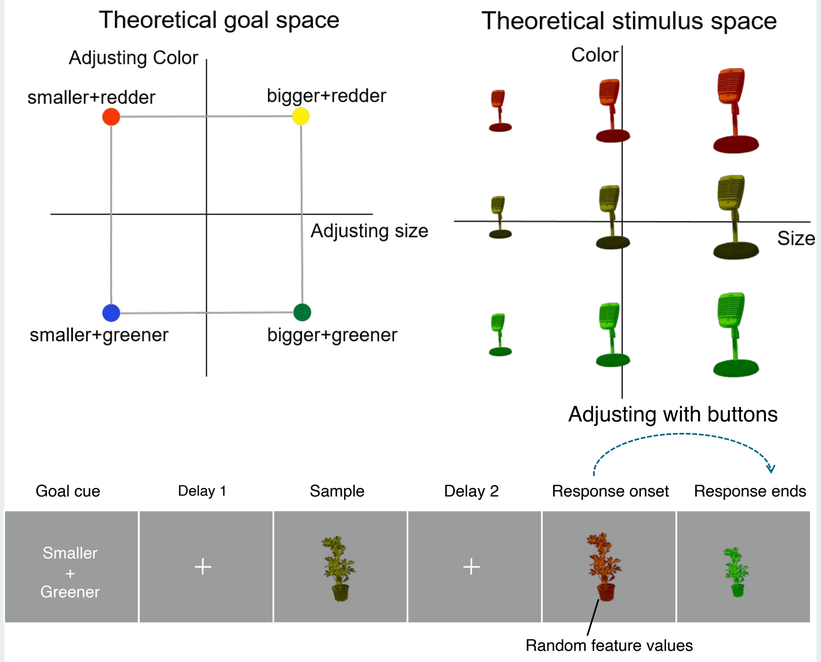
Background

- Main focus in working memory (WM) research has been specific contents: e.g. angles, colors, objects, etc.
- Neural principles for maintaining and organizing abstract, higher-order task information are relatively unknown.
- Abstract WM involves more higher-level association regions.

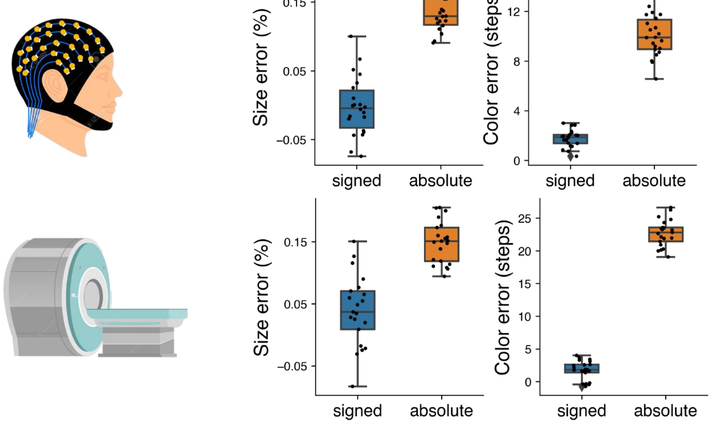


Task and stimuli

- The abstract WM task combines task goals and specific sample features.



- We used both EEG (N = 22) and fMRI (N = 21)

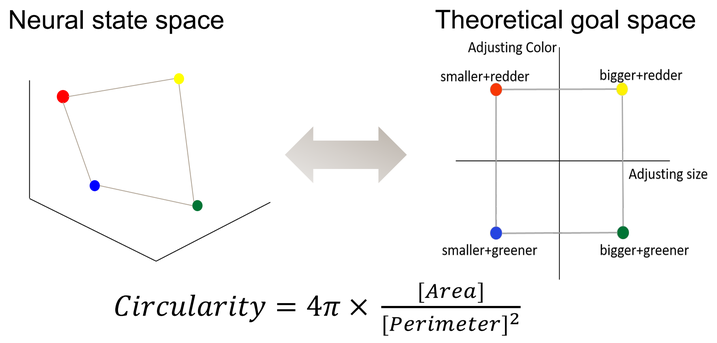


Research questions

- Does the brain organize abstract WM in a structured way?
- How does the interaction between abstract and specific contents take place?

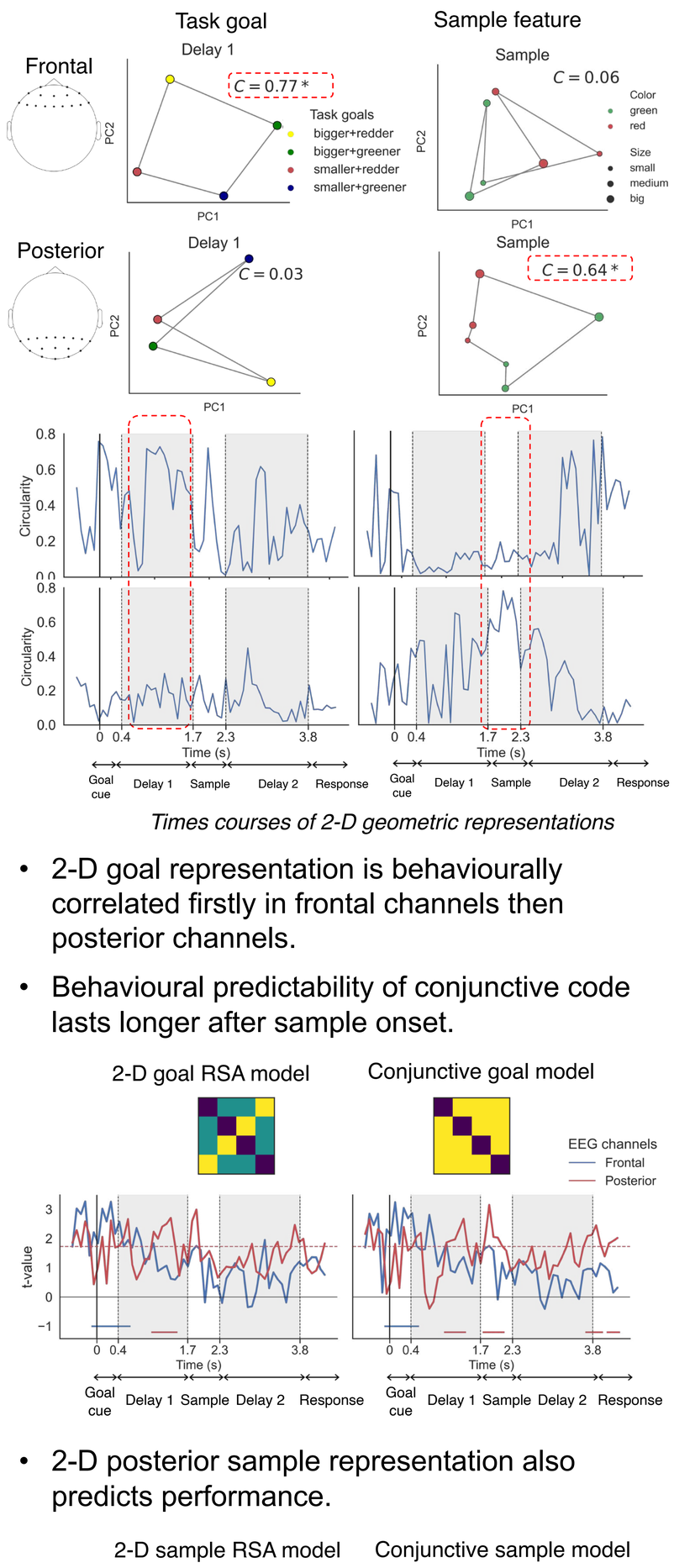
Result 1

- PCA-based neural subspace



$$Circularity = 4\pi \times \frac{[Area]}{[Perimeter]^2}$$

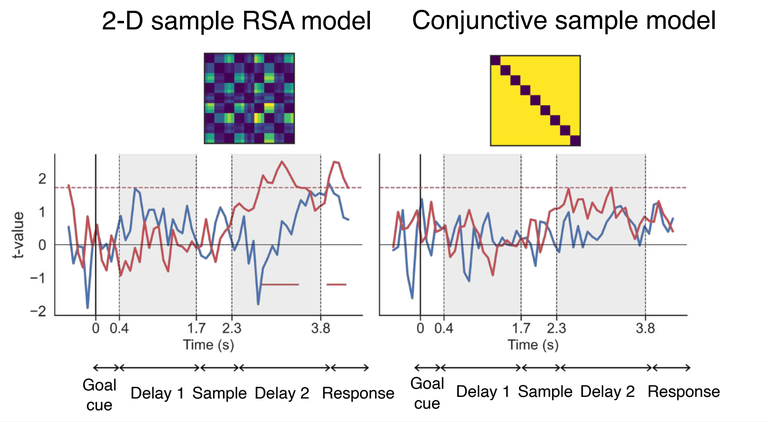
- Neural geometries consistent with designed spaces exist in selective sites.



Times courses of 2-D geometric representations

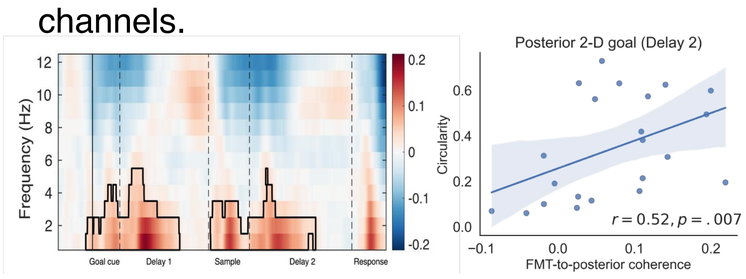
- 2-D goal representation is behaviourally correlated firstly in frontal channels then posterior channels.
- Behavioural predictability of conjunctive code lasts longer after sample onset.

- 2-D posterior sample representation also predicts performance.

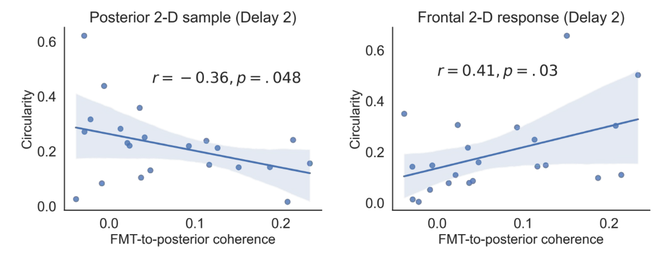


Result 2

- Frontomedial theta (FMT) to posterior coherence at both delays mediates the 2-dimensional goal representation in posterior channels.

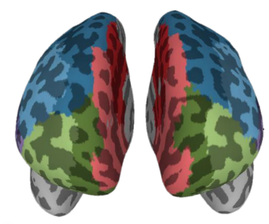


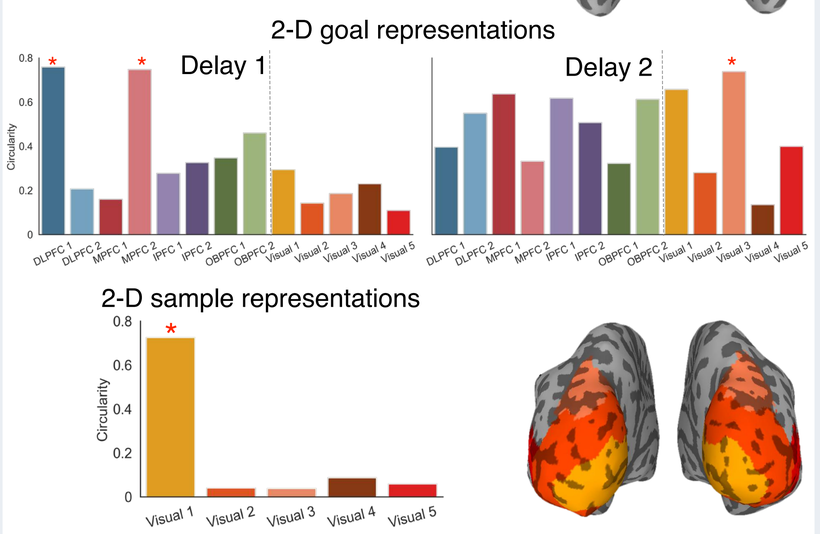
- FMT is also negatively correlated with 2-D sample & positively with 2-D response codes.



Result 3

- PFC contains 2-D goal code in Delay 1.
- Dorsal visual area in Delay 2.





Conclusions

- Abstract goal-related WMs are organized in a low-dimensional format consistent with the task space in PFC during maintenance and in visual areas during implementation.
- 2-D sample representations are found exclusively in visual areas.
- FMT coherence transfers 2-D goal information to posterior area where integration with sample representation takes place.
- Together, EEG and fMRI have provided converging evidence for an organizing principle of abstract WM and mechanisms for goal-directed stimulus manipulation.

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