Real-time neurofeedback of working memory usage during prospective remembering

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Introduction: Prospective memory

How do we remember to execute a specific goal at the appropriate time despite busyly pursuing other tasks?

Theories of cognitive control and prospective memory (PM) suggest that we can either use proactive control to actively maintain goal information in working memory—e.g., to mentally rehearse “stop at the library”—or we could use reactive control (to rely on cue-based retrieval of goal information from episodic memory—e.g., seeing the library on the way home reminds us to stop).

The flexible choice of strategy for a particular goal involves effort-performance trade-offs that depend on the availability of cognitive resources and the likelihood of goal retrieval.

We developed a prospective memory paradigm for fMRI consisting of a picture-target detection task (face & scene) embedded in an ongoing back task (direction of motion).

Task design and behavioral results

We used a proactive control strategy and found that prospective memory accuracy was associated with better subsequent prospective remembering.

Prospective memory cost (PM cost) is the decrement in performance from detecting targets when they are embedded in an active ongoing task compared to when they are in a passive control condition.

fMRI decoding performance and simulated neurofeedback

We were able to successfully decode the contents of working memory using the entire amount of training data as would be available in real-time. Stronger target category evidence was associated with better subsequent prospective remembering.

fMRI pattern classification

1. Train L1-regularized logistic regression classifiers, using cross-validation, on data from the delay period of each trial:
   - face-target (correct delayed recall vs. incorrect delayed recall)
   - scene-target (correct delayed recall vs. incorrect delayed recall)
   - no-target (data only)

2. Use the trained classifier to decode the brain activation patterns at training and testing sets to avoid circularity.

- Real-time fMRI pattern classification can be used to guide their allocation of cognitive resources and maintain goal information in working memory throughout the trial.

- The target is proactively maintained in working memory throughout the trial.

- The ongoing task is made easier by increasing the motion coherence of the dots on the next stimulus display.

- Prospective memory accuracy can be improved by increasing the motion coherence of the dots on the next stimulus display.

- Future work: use fMRI pattern classification to identify strategy choice on a trial-by-trial basis. Suboptimal strategy choice was associated with lower performance on a PM task.

Conclusion

Can we use readouts of participants’ brain states to guide their allocation of cognitive resources and improve prospective remembering?

Real-time fMRI neurofeedback strategy

Neurofeedback: Providing visually guided feedback to a participant about some aspect of their cognitive state. Real-time analysis of fMRI data (rtfMRI) is one approach that is gaining popularity and has been developing rapidly. Most applications of rtfMRI to date have focused on univariate classification (i.e., training participants to up- or down-regulate neural activity in particular brain regions). deBettencourt et al. (2015) were among the first to use multivariate pattern classification to provide more sensitive readouts of a participant’s cognitive state for neurofeedback training.

Our approach:

1. Use fMRI pattern classifiers to readout the activation of the prospective memory target category in working memory on a moment-to-moment basis.

2. If working memory engagement is too low, make the ongoing task easier by increasing the motion coherence of the dots on the next stimulus display.

3. An easier ongoing task frees up cognitive resources for the prospective memory task allowing for shift to optimal strategy.

With an ongoing task that demands fewer cognitive resources, participants can reallocate these resources for prospective remembering.