Neural evidence for the flexible use of working memory & episodic memory in prospective remembering

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Introduction: Prospective memory

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

- e.g., Must I remember to pick up my son from his karate lesson on my way home from work tonight?

Theories of cognitive control (e.g., by Braver and colleagues) and of prospective memory (e.g., by McDanel and colleagues) suggest that we can either use proactive control (to activate and maintain the goal information in working memory — e.g., to mentally rehearse “stop at the karate studio”), or we could use reactive control (to rely on cues to retrieve goal information from episodic memory — e.g., seeing the karate studio attire the driver reminded me to stop).

The flexible choice of control strategies is likely to depend on the availability of cognitive resources and the likelihood of goal retrieval.

Task design and behavioral goals

We developed a prospective memory paradigm for fMRI consisting of a picture target detection task (faces & scenes) embedded in an ongoing n-back task (lexical judgments).

Prospective Memory

We are developing normative computational models that formally specify the costs and benefits associated with different memory strategies. These models will generate fine-grained predictions about people’s choice of working and episodic memory resources in order to optimize performance.

When a participant’s performance deviates from the model’s predictions regarding optimal strategy choice, there are two possible explanations:

1. Our model of optimal performance is wrong and needs to be updated
2. The person is behaving suboptimally (i.e., they could do better by adjusting strategy)

To abet these possibilities, we will use real-time fMRI neurofeedback to train people to use the strategy that the model predicts is optimal.

Using methods that we recently developed at Princeton, we will apply fMRI decoding in real time to derive a readout of how much the person is relying on working memory vs. episodic memory, and the person will be encouraged to adjust their strategy use to bring it in line with the model; if the model’s predictions about optimal strategy use are correct, following this feedback loop will lead to an improvement in memory performance.

Hypothesis and experimental approach

Both working memory and episodic memory strategies predict that target activation at the point of target reappearance will predict prospective memory accuracy.

However, if participants are using a working memory strategy, then:

(a) Target activation before the point of target reappearance should also predict prospective memory accuracy.

(b) Suppression of lexical decision processing before the point of target reappearance should also predict prospective memory accuracy.

Analysis strategy

Use fMRI pattern classifiers to read out the activation of the target on a moment-to-moment basis. Use these neural measures to predict whether people will identify the target when it reappears at the end of each trial.

Relating target activations to prospective remembering

Identify “target-sensitive” regions

- Contrast: Trials with a target during the n-back lexical decision task vs. Trials without a target during the n-back lexical decision task.

Note: Sensory stimulation is identical during the lexical decision task in both trials (i.e., face, scene, and letter string appear on the screen every 2 sec).

MRMI pattern classification

1. Train a 4-way L2-regularized logistic regression classifier, using cross-validation, on data from the lexical decision and rest phases of each trial:

   a) four target trials
   b) no target trials (lexical decision only)
   c) no target trials (lexical decision & n-back trials)
   d) baseline trials (before trials)

2. Use the trained classifier to decode the brain activation patterns at the point of target reappearance

Also, use a classifier trained on the lexical decision activity associated with higher prospective memory. Note: Only Whole brain trials showed this prior to target reappearance.

Results

Stronger classifier readouts for the target vs. both before and after its reappearance were associated with better prospective memory.

This was stronger in WMbias than EMbias:

- Low proactive interference and higher working memory load (1-back) should bias participants to rely on episodic memory to identify the target at the moment that it reappears.

- High proactive interference should interfere with episodic memory retrieval, and low working memory load (2-back) should bias participants to use working memory to maintain the target throughout the trial.

5 Future directions: Modeling & training

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7 Take home points

1. We used fMRI pattern classifiers to read out the memory strategy on a moment-to-moment basis, and we used these neural measures to predict whether people would identify the target when it reappeared during a test of prospective memory.

2. Stronger classifier readouts for the target vs. both before and after its reappearance were associated with better prospective memory.

3. Anticipatory activity in cognitive control regions (including anterior PFC), a region implicated in prospective remembering, e.g., Koelstra and Hyafil, (2011), led to a tighter coupling between working memory activations and prospective target activations and weaker lexical decision activity were associated with better prospective memory.

However, memory performance did not suffer under low anticipatory control; stronger target activations in response to the target appearance on hits suggests the use of reactive control, i.e., retrieval of the target from episodic memory.

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