Principles of Memory: Striatal & Hippocampal Contributions to Different Forms of Learning

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Cold Spring Harbor, April, 2009

Distinct Memory Systems

<u>Declarative</u> Rapid Flexible <u>Procedural</u> Gradual Specific



Medial Temporal Lobe

Basal Ganglia

E.g. Mishkin et al., 1984; Squire, 1994; Gabrieli, 1998; Packard & McGaugh, 1996; Knowlton et al., 1996; Robbins, 1996; Squire & Zola-Morgan, 1996

Distinct Memory Systems

BUT, NOT SO SIMPLE....



BUT, NOT SO SIMPLE....

Data are not consistent

E.g. Schenden et al., 2003; Degonda et al., 2005; Kesner et al., 1993; Packard and McGaugh, 1992; Poldrack et al., 2001; Owen et al., 1993; Witt et al., 2002; Weintrab et al., 2004; Higginson et al., 2005

Anatomy not entirely consistent

Rationale

Examine both incremental feedbackbased learning and subsequent generalization.

> Cognitive mechanism? Neural mechanism?

Outline

Patients & Functional imaging (a) incremental learning (BG?) (b) generalization (MTL?)

Emerging Principles Memory integration Mnemonic prediction errors

Acquired Equivalence

<u>Design</u>: Two stimuli predict same outcome and later are treated as "equivalent" so knowledge about one generalizes to the other.

E.g. Grice & Davis, 1960; Bonardi et al., 1993; Hall & Honey, 1989







Which picture does this person prefer?





Acquired Equivalence Phase 1: Learning FEEDBACK











Questions Mechanism: Learning, or test? 1. 2. Evidence for interactive systems?

Learning



Shohamy & Wagner, Neuron, 2008

Learning

Test



Shohamy & Wagner, Neuron, 2008

Learning

Test



Learning

Test



Different neural systems?

If so, when? During learning, or during test?

Hippocampal activity during test does NOT predict generalization





Hippocampal activity during learning predicts generalization





Generalization Performance

Shohamy & Wagner, Neuron, 2008

and midbrain Hippocampal activity during learning predicts generalization





Shohamy & Wagner, Neuron, 2008

Localization of midbrain activation



Consistent with VTA

Midbrain-Hippocampal Interaction ?

Midbrain-Hippocampal Interaction



Shohamy & Wagner, Neuron, In Press

Midbrain-hippocampal cooperation



What about the basal ganglia?

BG activity does not correlate with generalization...





...but does correlate with learning

Summary

I. Hippocampal and midbrain processes during learning predict subsequent generalization

- II. Cooperative interaction between them
- III. Dopamine may modulate both learning and generalization (via different circuits)

(E.g. Shohamy et al., 2006; Shohamy et al., 2009)

Open Questions

What about the MTL-BG interaction?

Pushing" each system:
reward learning (Daw & Shohamy, 2008; Wimmer et al., In Prep)
novelty vs. experience (E.g. Clement et al., In Prep)

Principles of Memory

1. Flexibility = Integration



Principles of Memory

1. Flexibility = Integration

2. Prediction errors may provide one mechanism

Dopamine, Prediction & Learning



Schultz and colleagues

Dopamine signals the occurrence of an unexpected reward

... or EVENT?

Acknowledgements

The Shohamy Lab @ CU

Karin Foerde Nathan Clement Jenna Reinen Elliott Wimmer Keva Garg Barbara Graniello

Michael Szeto

<u>Collaborators</u>

Anthony Wagner

Nathaniel Daw

Mark Gluck

Itamar Kahn

Natasha Kirkham

Catherine Myers

Carol Tamminga

THANK YOU