Feedback Matters: Effects of Feedback Properties on Category-Learning

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Two separate learning systems

Explicit, *Hypothesis-testing* system mediates learning of “rule-based” (RB) category structures.
  - Frontally mediated
  - Verbalizable rules

  - Striatally mediated
  - Stimulus response associations reinforced by feedback

(Maddox and Ashby, 2004; Ashby et al., 1998)
Can use Category Learning Tasks to examine how feedback affects the two systems

**Approach** - Use simple tasks to examine complex effects of feedback on the two systems

**Rule-Based (RB)** – how feedback affects Hypothesis – testing system

**Information-Integration (II)** – how feedback affects Procedural system
Rule-Based Task

Optimal rule can be implemented
No verbalizable rule can be used
Competition between systems

• Hypothesis-testing system competes with Procedural system for control of the response.
• Hypothesis-testing system initially controls the response
  -Participants first try explicit rules
• Control is gradually passed to the Procedural system in II tasks.
Two ways to enhance procedural system

• Decrease the reliance on the Hypothesis-Testing System
  – Less use of explicit rules leads to better II learning
  – Control passed to Procedural System

• Directly enhance procedural system
  – Optimal feedback timing needed to reinforce stimulus-response associations.
  – Long delays between response and feedback hurt II learning. (e.g. Maddox & Ing, 2005)
Experimental Manipulations

• Examine two feedback properties to determine their effect on category-learning
  – Stimulus Presence (vs. Absence)
    • Should help Hypothesis-testing system
      – Less WM demands with stimulus present
      – Stimulus there to evaluate after feedback
    • Delays the transfer of control to the Procedural System
  – Feedback delay
    • Should directly affect the Procedural system
    • Feedback needs to come at an optimal time for the system to learn
    • Longer delay leads to worse II learning
Stimulus Present vs. Absent

Stimulus Present
- More information helps RB, hurts II (Maddox et al., 2008)

Present
- Stimulus Appears
- Feedback Delay
- 3500ms feedback time

Absent
- Stimulus Appears
- Feedback Delay
- 3500ms feedback time
Feedback Delay (0ms, 500ms, 1000ms)

Long Feedback Delay
- Hurts performance on II tasks
- Has no effect on RB tasks
  (e.g. Maddox, Ashby & Bohil 2003; Maddox & Ing, 2005)
Experiment 1

- 2 X 2 X 3 design
  - 2 (Category Types) X 2 (Stimulus Presence) X 3 (Feedback Delay intervals)
- 5 80-trial blocks
Predictions

- Stimulus Present conditions should do better
- Feedback Delay should have no effect

- Stimulus Absent conditions should do better
- Performance worse with longer feedback delays
Results - Overall Accuracy

Stimulus Present conditions better for RB

Best Performance for Stimulus Absent with 500ms Delay
-Not the predicted monotonic decrease with delay interval
Decision Bound Modeling

• Best-fitting model gives information about which strategy each participant probably used to classify the stimuli

• Could be Fit by Rule-Based, Information-Integration, or Random Response Models

• Examined the proportion of data sets best fit by the optimal model over the final three blocks of the task
RB model fits

- More RB participants in Stimulus Present conditions fit best by unidimensional rule model along the spatial frequency dimension
- More participants in the Stimulus Absent 500ms condition fit best by II models compared to all other conditions.
Why is 500ms better than 0ms?

• Need a small temporal delay between response and feedback.
  – Different groups of striatal neurons fire separately for response and feedback (e.g. Shidara et al., 1998).

• Small delay may heighten uncertainty, strengthen DA reward signal (e.g. Berns et al., 2001)
Experiment 2

- Varied Feedback times around 500ms
  - Low (SD=75ms)
  - High (SD=150ms)

- Stimulus was Absent for both conditions
  - Compared results to 500ms Absent condition from Exp.1
Experiment 2 Results

• Accuracy better with Low Variance than High Variance
  – Slightly better than 500ms (0 Variance) condition
Exp 2. Optimal Model Fits

About the same proportion fit best by II models in Low Variance and No Variance Conditions
Discussion

• Experimental Design
  – Feedback properties are not trivial

• Procedural system highly sensitive to feedback timing
  – Stimulus-response associations are best strengthened by small, consistent feedback delays.

• Implications for models of the two systems
  – System interactions
  – Optimal training conditions
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THE END
More RB participants in Stimulus Present conditions fit best by unidimensional rule model along the spatial frequency dimension.
More participants in the Stimulus Absent 500ms condition fit best by II models compared to all other conditions.
Discussion

• No surprise – RB performance better with Stimulus present throughout feedback.

• II performance better when stimulus was not present during feedback.
  – Optimal performance with 500ms feedback delay
Experiment 2 Results

- Accuracy better with Low Variance than High Variance
  - Slightly better than 500ms (0 Variance) condition
Exp 2. Model Fits

- About the same proportion fit best by II models in Low Variance and No Variance Conditions
  - Proportion fit best by rules identical across conditions
  - High Variance may disrupt procedural system itself
-By the final block the Stimulus Absent condition is nearly 20% more accurate