The Role of Eye Movements in Spatial Learning

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Introduction

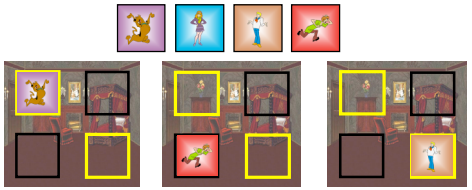
Implicit learning is an essential aspect of human behavior, allowing individuals to learn from their surroundings without explicit instruction. Studies exploring sequence, statistical, or artificial grammar learning have documented a core sensitivity to predictable information. Recent results have shown that adults successfully learn both complex spatial and object identity sequences, while children show successful learning of only spatial sequences (Markant et al., 2007). One possible explanation for this discrepancy is that shifts of attention and eye gaze provide additional information that supports greater learning during spatial tasks. In the current study, we explore the role of attention and eye movements during implicit learning of spatial and object sequences. Evidence for enhanced object learning when attention shifts are introduced and/or reduced spatial learning when eye movements are eliminated would suggest that eye gaze and attention shifts are an important component of sequence learning. Finally, varying effects of these manipulations among children and adults would suggest that the cognitive learning process may be differentially coupled with perception and action processes across development.

Questions

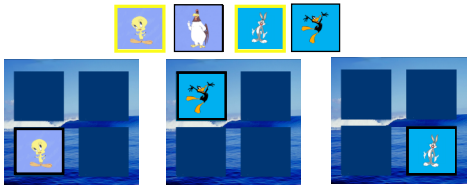
1. **Does the presence or absence of attention shifts and eye movements affect learning of complex object and spatial sequences?**
2. **Are there developmental differences in the extent of learning in these contexts?**

Study Design

SPATIAL Sequence: **Repeating pattern of spatial locations**
Multiple objects; Identity info irrelevant



OBJECT Sequence: **Repeating pattern of stimulus identities**
Multiple locations; Location info irrelevant



Sequence Structure

Design: Identical 10 - step partially ambiguous sequence with interleaved random & sequence trials

Awareness: Subjects were queried for explicit awareness of the sequence following each task

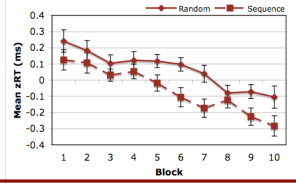
- 84 trials per block
- 10 blocks of trials for each task

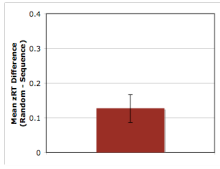
Measure of Learning

- Successful sequence learning indicated by faster reaction times on sequence trials compared to random trials

  **Note: Reaction times are standardized based on individual's mean reaction time due to group differences in overall reaction time

- Our measure of learning is the mean difference between standardized reaction times on random versus sequence trials





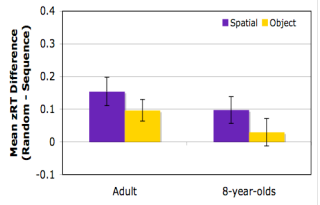
Experiment 1: Attention Shifts

Accuracy

- **Adults showed greater overall accuracy than children (98.9% vs. 97.2%)**
- **No difference in accuracy across the two tasks**
- **No difference in accuracy on random vs. sequence trials**

Learning Effect

- **Among adults, magnitude of learning effect was equivalent across tasks**
- **Children showed significant learning effect on spatial task but not object task**



Acknowledgements

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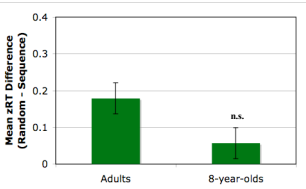
Experiment 2: Restricted Eye Movements

Inclusion Criteria

- **Adults: Maximum 5 eye movements per block (~5% of trials)**
- **8-year-olds: Maximum 20 eye movements per block (~25% of trials)**

Accuracy

- **Adults showed greater overall accuracy than children (99.2% vs. 96.6%)**
- **No difference in accuracy on random vs. sequence trials**

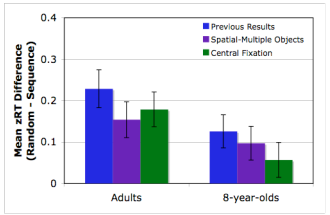


Learning Effect

- **Adults showed significant learning effect when eye movements were eliminated**
- **Children showed no significant learning effect when eye movements were eliminated**

Spatial Task Comparison

- **Adults showed greater overall learning effect than children**
- **Among adults, magnitude of learning effect was equivalent across tasks**
- **Children showed learning effect on spatial tasks until eye movements were eliminated**



Conclusions

- The role of attention shifts and eye movements differs across spatial and object sequence learning. Introducing shifts of attention and eye gaze does not enhance learning of objects sequences.
- **Eye movements may support learning only when they are relevant to the information being learned.**
- Spatial sequence learning is not "just" motor learning; spatial sequences can be learned in the absence of eye movements. However, the importance of eye movements during spatial learning varies across development:
  - For 8-year-olds, eye movements are necessary *and* sufficient for learning of complex spatial sequences. For adults, eye movements are sufficient *but not necessary* for learning the same sequences.
- **Cognitive learning process may be more tightly coupled to perception-action processes earlier in development.**