# Working memory resolution increases faster than capacity in visuomotor sequence learning

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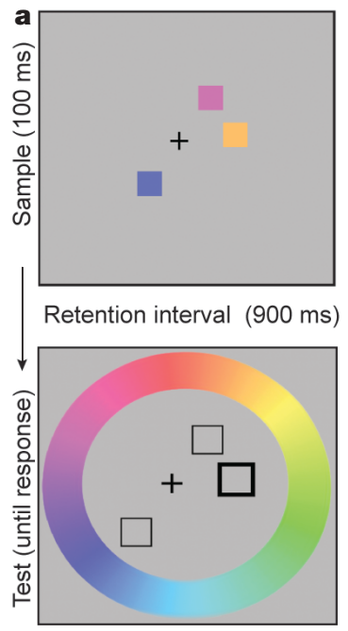
# Extending the study of visual working memory: sequences and learning

- Visual working memory can be modeled with Gaussian + uniform mixtures

  (Zhang & Luck, 2008; Bays & Husain, 2008; Bays & Husain, 2009; Gorgoraptis et al., 2011; Bays et al., 2011; Zokaei et al., 2011; Zhang & Luck, 2011)

  - Memory **resolution**
  - Memory **capacity**




from Zhang & Luck, 2008

# Extending the study of visual working memory: sequences and learning

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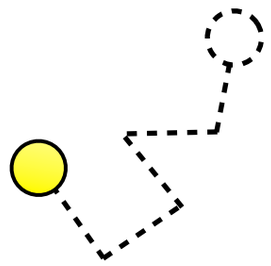
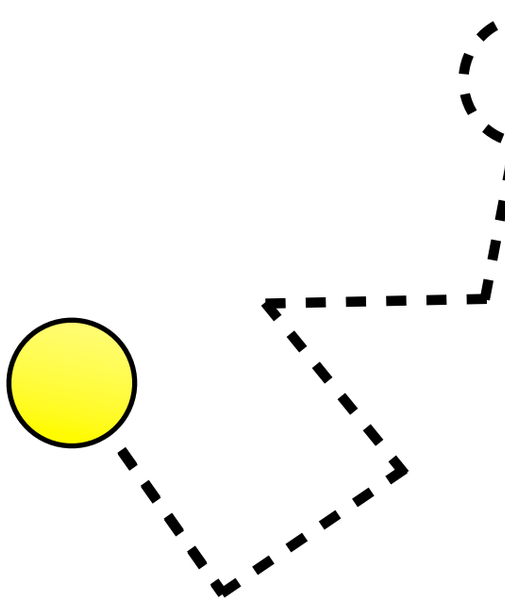
  - Memory **resolution**
  - Memory **capacity**

- Two new domains of investigation:

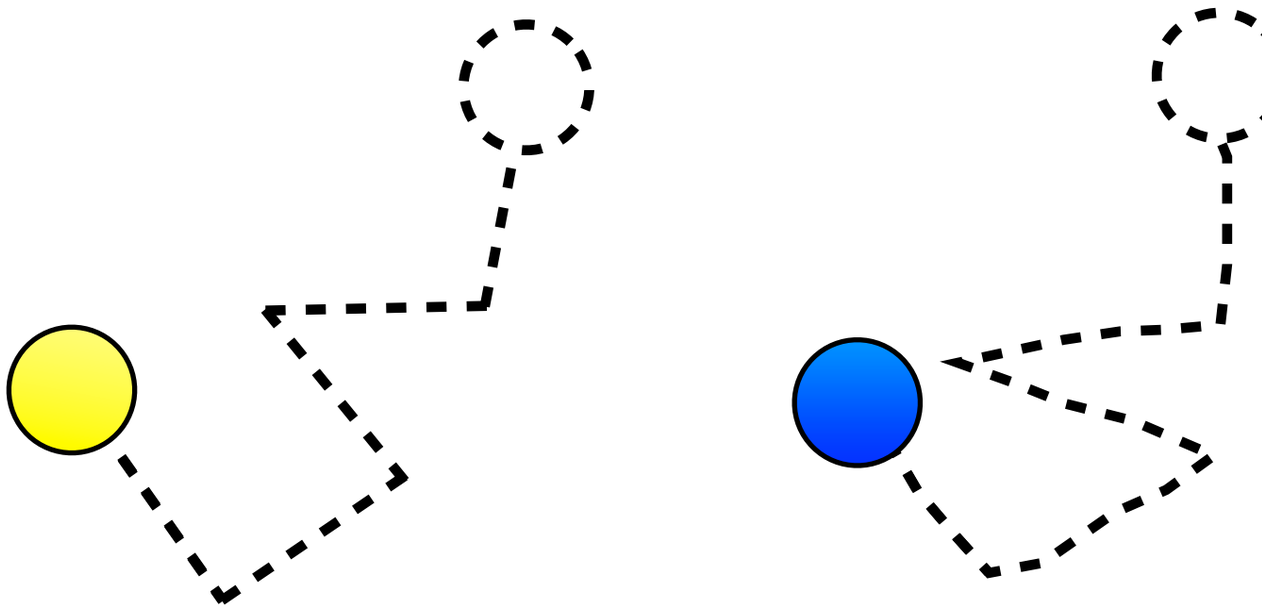
  - **Serial position effects**
  - **Effects of increased familiarity**



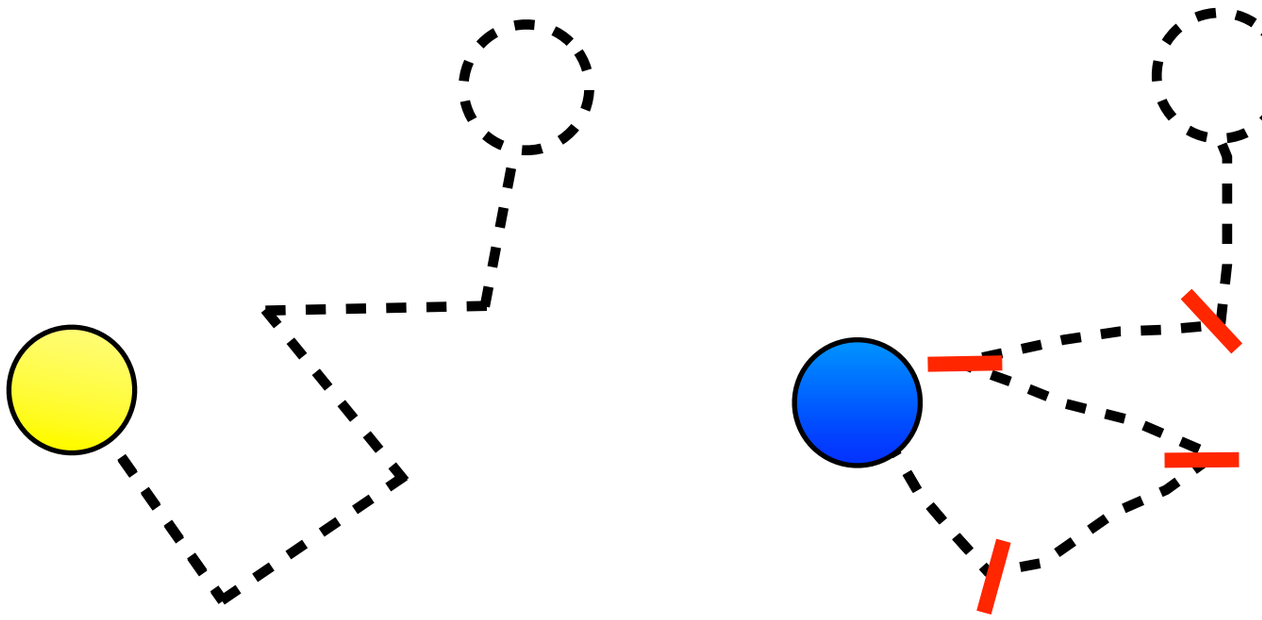
# Model sequence



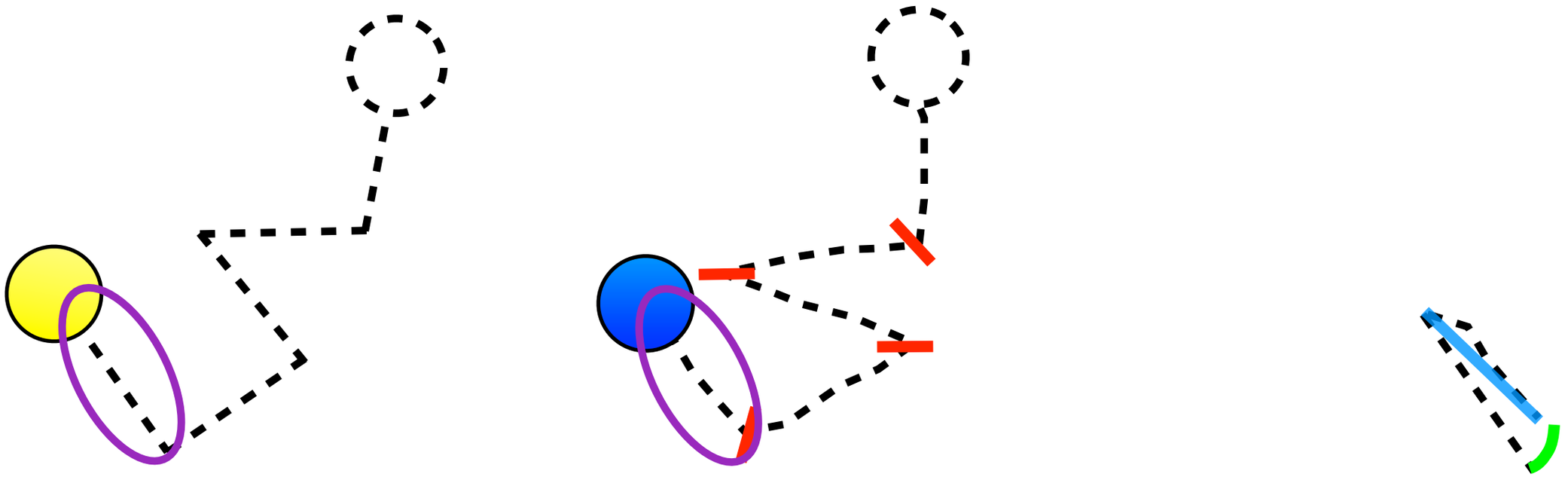
# Imitated sequence



# Segmentation



# Directional error



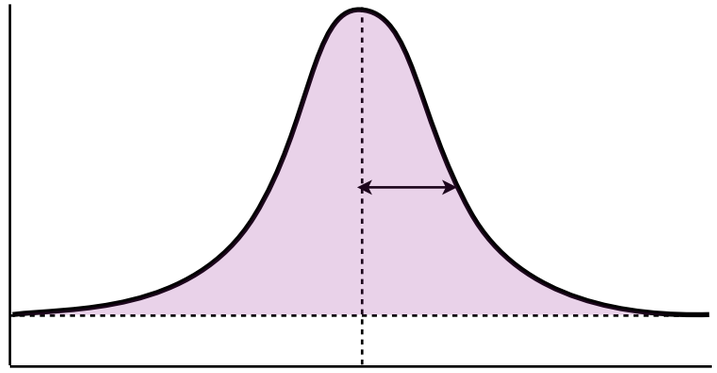
# Studying learning using these sequences

- Participants saw and reproduced each stimulus several times in succession.
- Measured directional error for each segment on each presentation of every trial.

| Dataset | Segments in stimulus | Presentations per trial | Number of trials | Number of subjects | Published in |
|---|---|---|---|---|---|
| **A** | 5 | 4 | 76 | 12 | Agam et al. (2007) |
| **B** | 5 | 4 | 88 | 12 | Noyce & Sekuler, in prep |
| **C** | 5 | 4 | 88 | 9 | Noyce & Sekuler, in prep |
| **D** | 6 | 5 | 76 | 12 | Agam et al. (2007) |
| **E** | 6 | 5 | 72 | 8 | Maryott, Noyce & Sekuler (2011) |
| **F** | 6 | 5 | 72 | 11 | Maryott, Noyce & Sekuler (2011) |

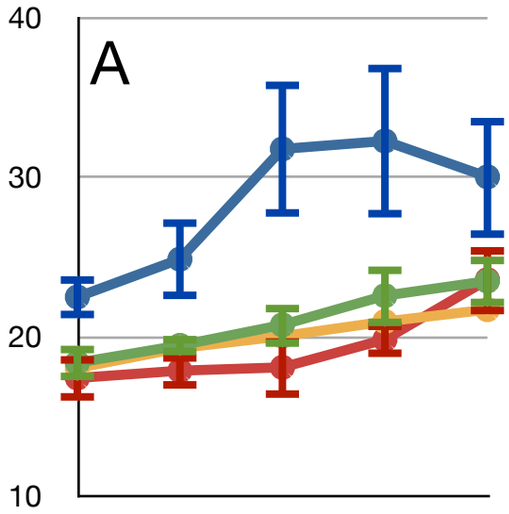
# Assessing memory's resolution and capacity

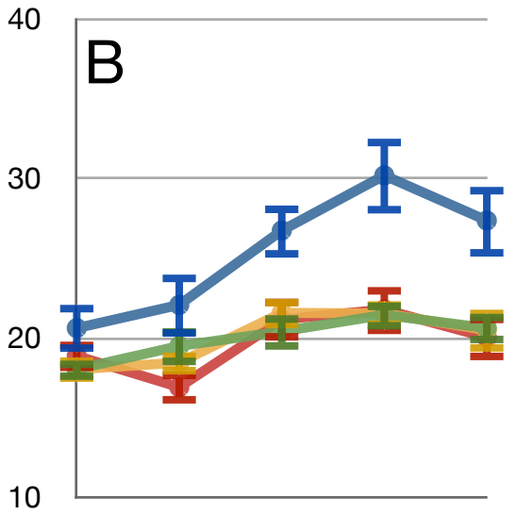
- Created distributions of errors for each participant × segment × repetition.
- Fitted Gaussian + uniform model, recorded two parameters:
  - SD of the Gaussian reflects memory **resolution**
  - Proportion of trials within the Gaussian component relates to memory **capacity**

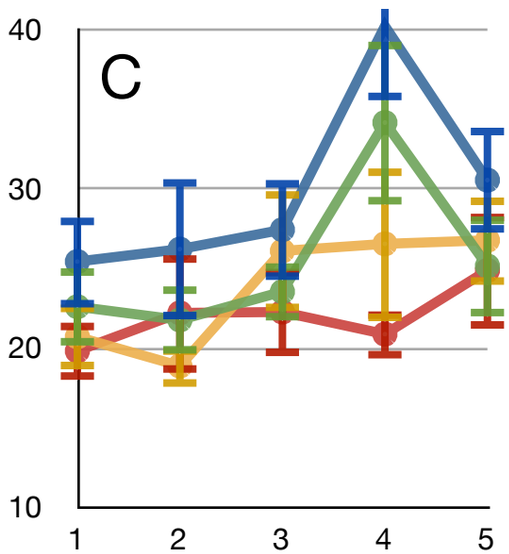


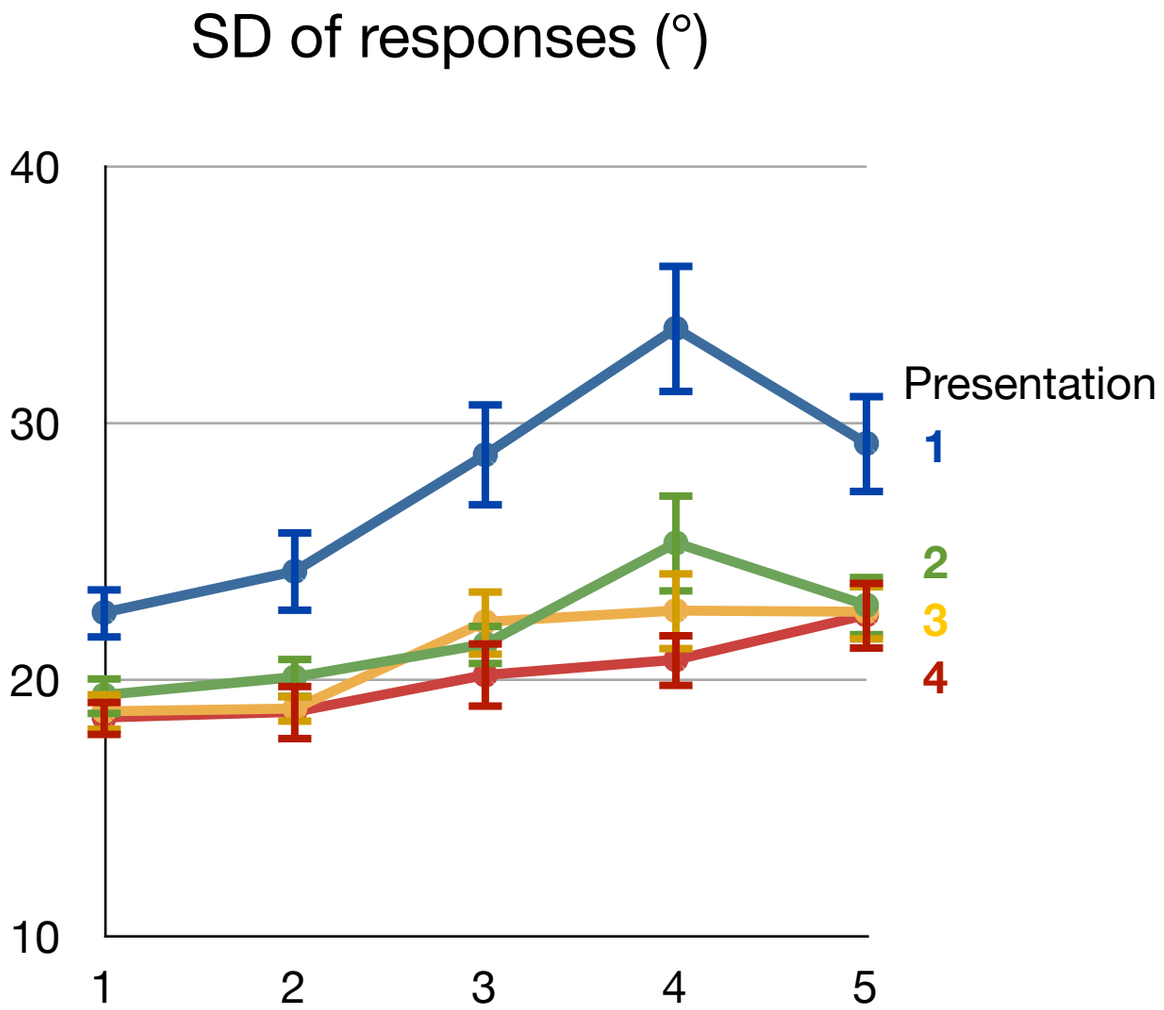
- Assessed serial position dynamics of each parameter.

# Memory resolution: 5-segment stimuli

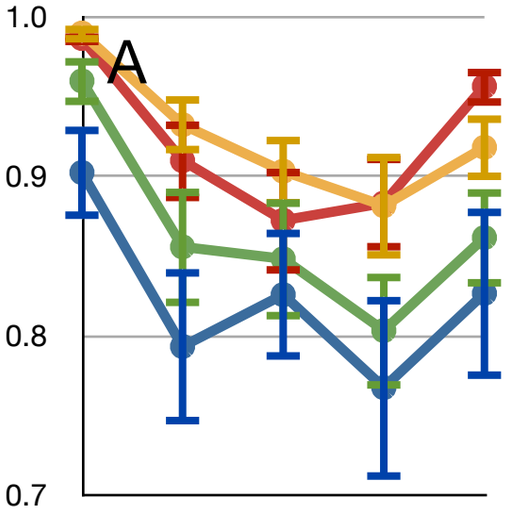


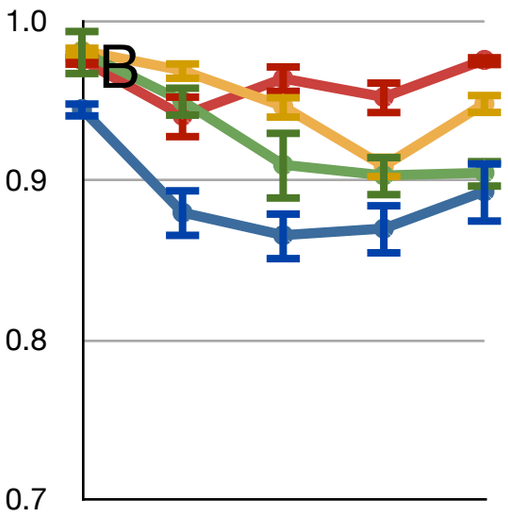



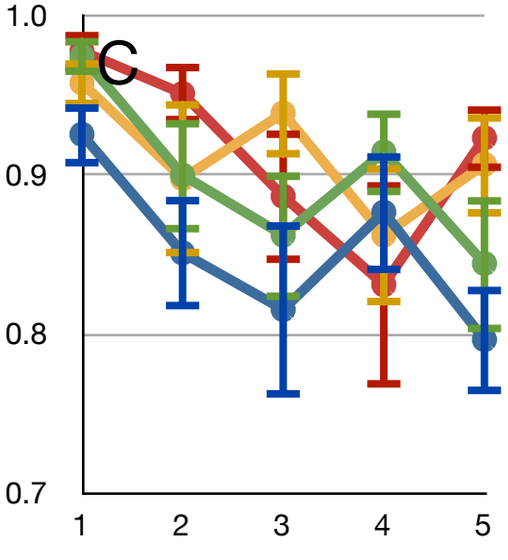



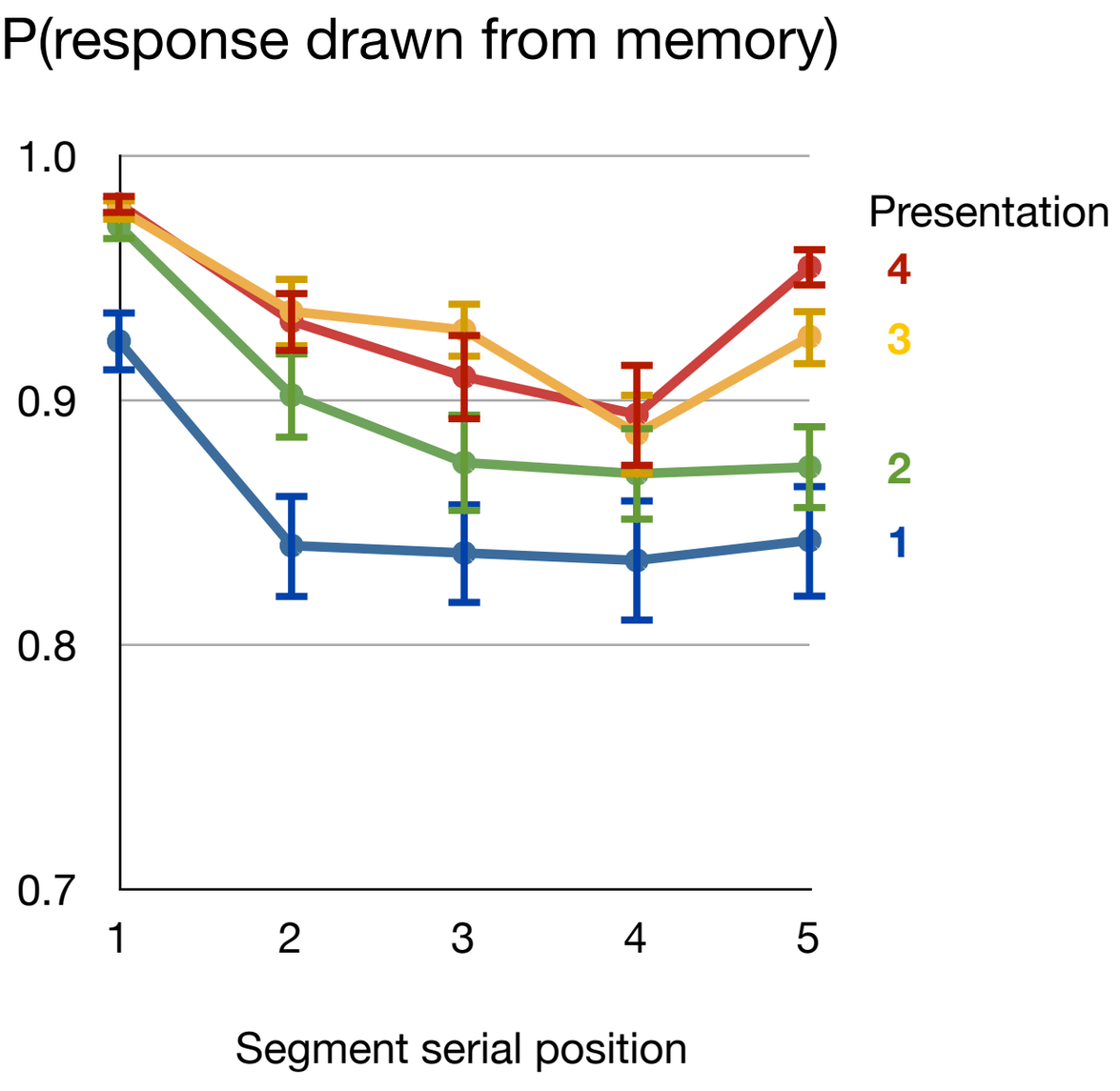



# Memory capacity: 5-segment stimuli

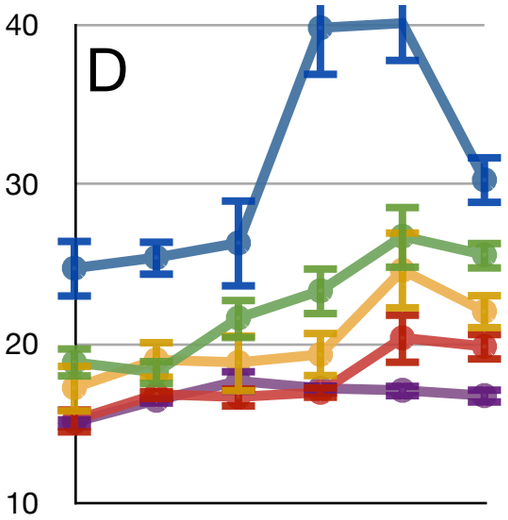


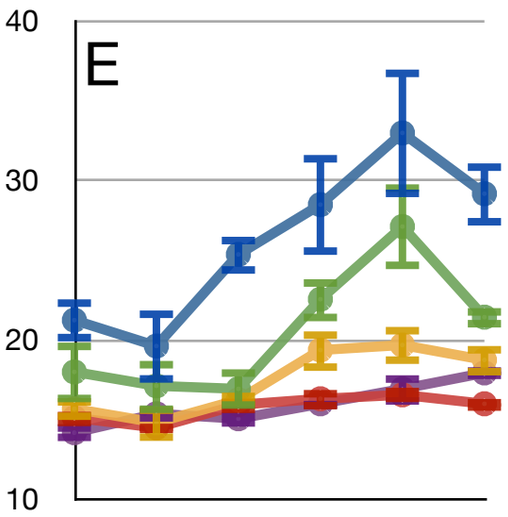



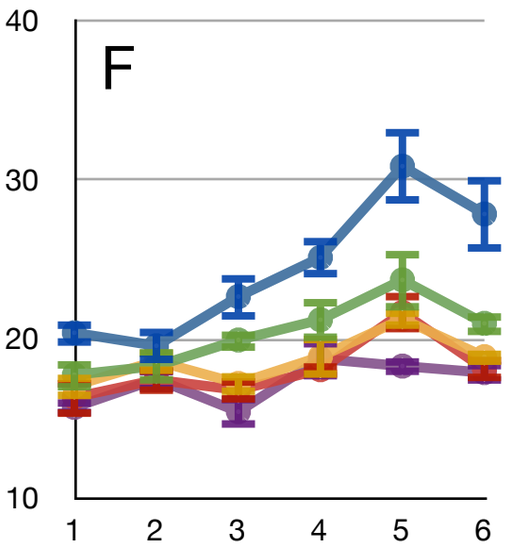



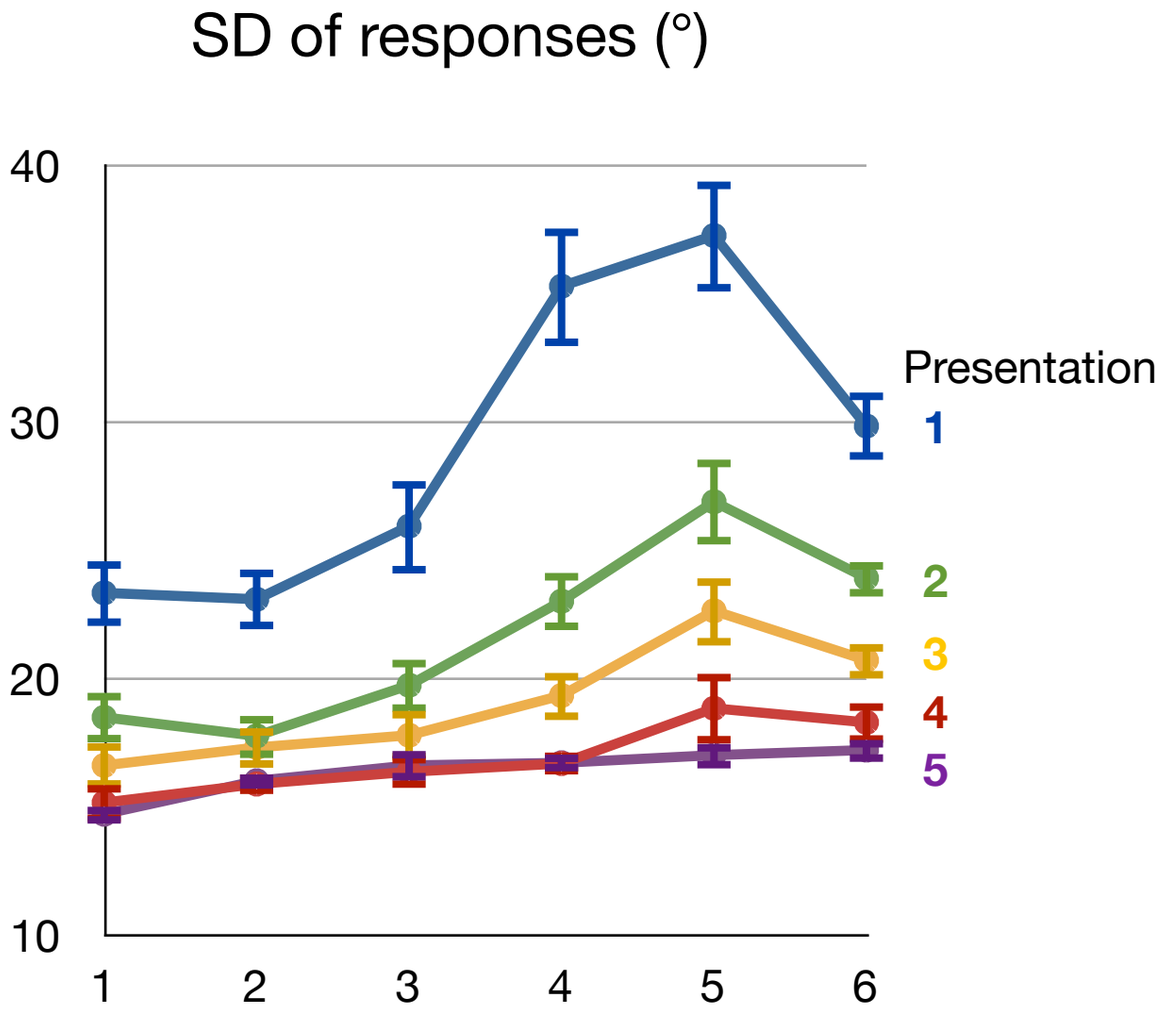



# Memory resolution: 6-segment stimuli

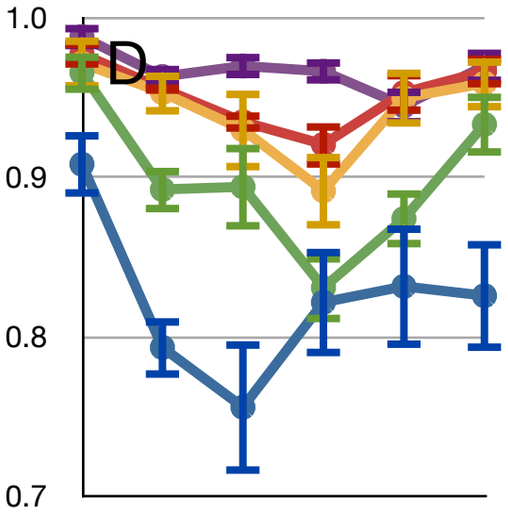


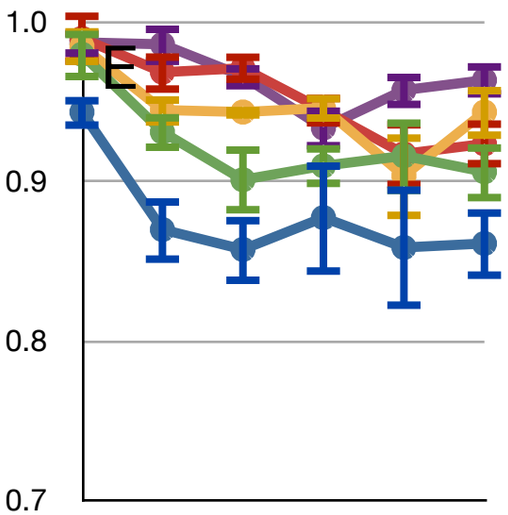



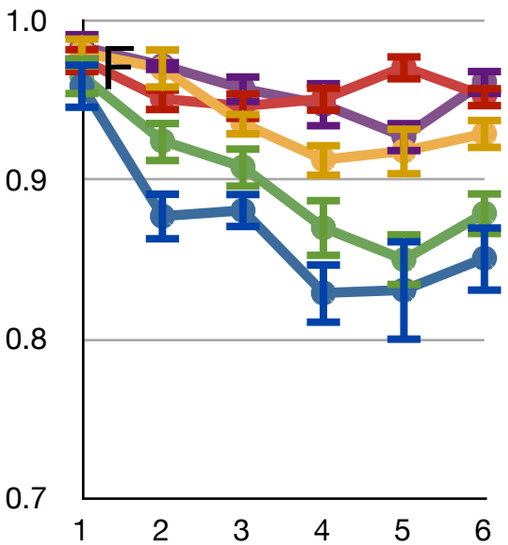



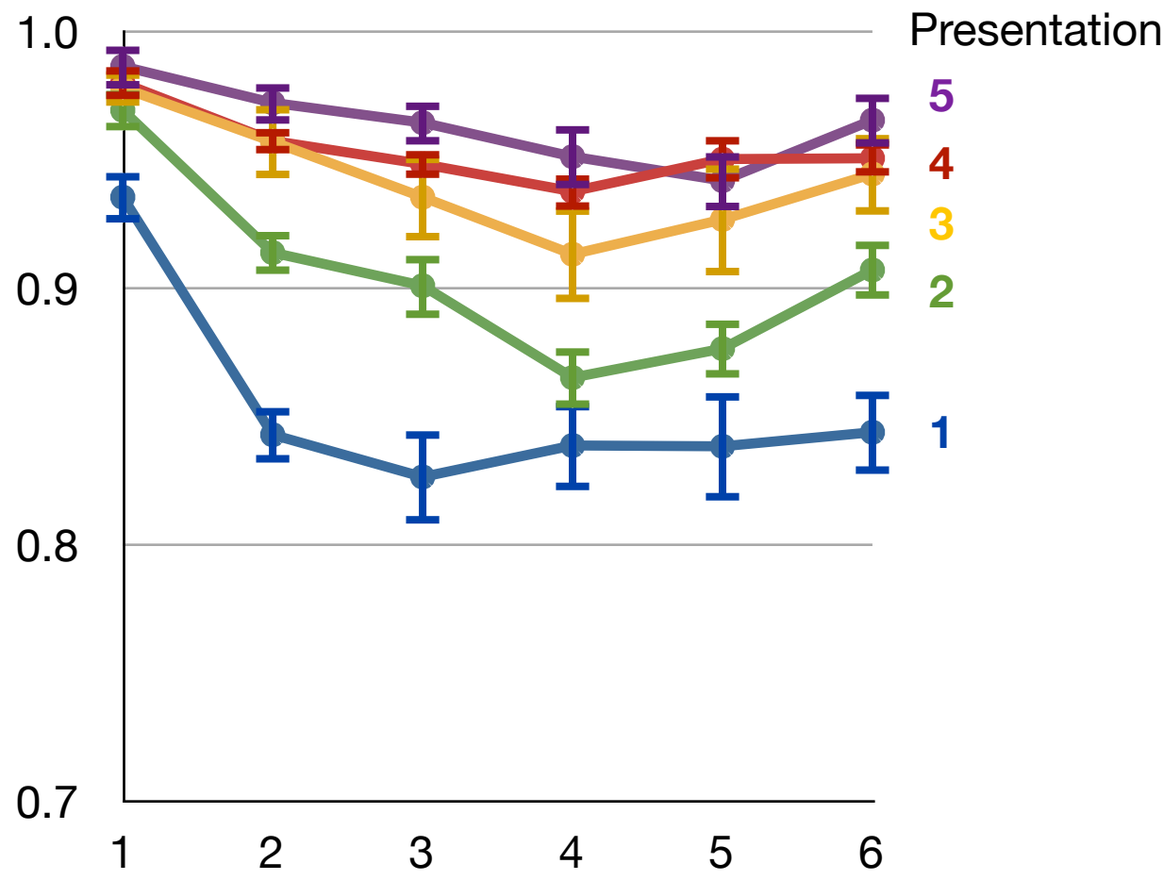
# Memory capacity: 6-segment stimuli



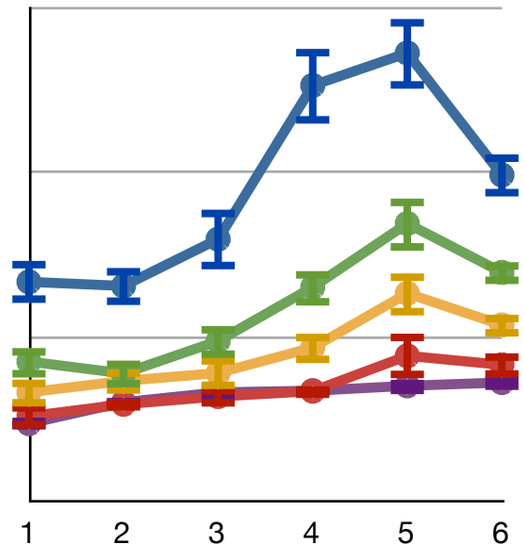

P(response drawn from memory)




Segment serial position

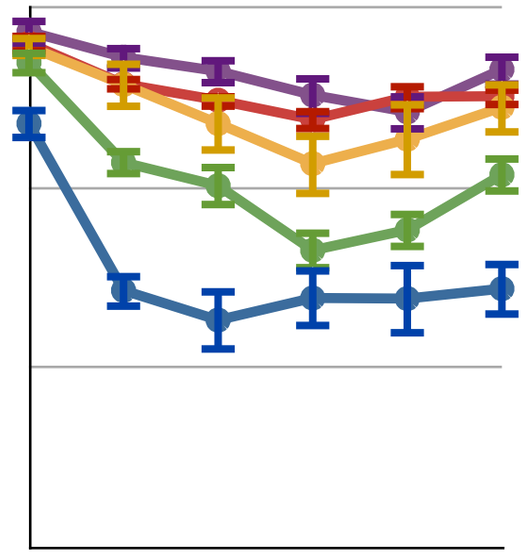
# Serial position dynamics of resolution

- SD has a strong serial position curve that quickly flattens and hits ceiling.
  - There is a limit on how precisely memory representations can be maintained, and that limit is reached quickly for most items.
  - Serial-position-curve flattening mostly derives from SD changes.
- Serial position dynamics suggest that remembering an already-familiar item requires fewer resources.



# Serial position dynamics of capacity

- P(response drawn from memory) shows gradual increase and gradual flattening over repeated exposures.
    - Steady improvement in accuracy derives from increases in P(memory) rather than decreases in SD.
- With increased familiarity, people can more effectively get stimuli into memory.
    - Chunking?
    - Support from LTM?
    - Other source of increased efficiency?



# Conclusions

- Serial-position dynamics with learning derive from changes in both **resolution** and **probability-of-memory**.

- More resources are required to encode not-yet-familiar items, reducing the precision of short-term memory.

- Items are more successfully placed into memory as a sequence becomes familiar.

# Thank you!


- Thanks to
  - Brandeis Vision Lab
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