Theories of Serial Order

PSYC201: Cognitive Psychology

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Week 7

Learning Objectives

- Three Theories of Serial Order:
  1. chaining theory
  2. positional theory
  3. ordinal theory
- Critical Tests:
  1. serial position curve
  2. list length effect
  3. error patterns
  4. grouping effects
  5. phonological similarity effect

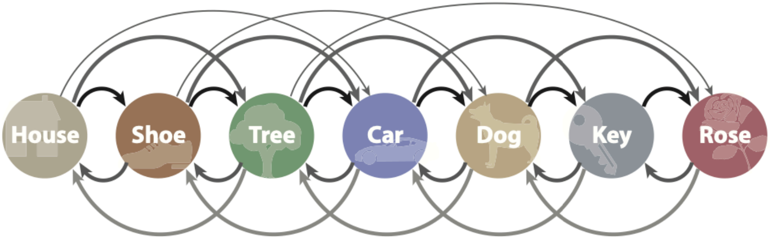
Three Theories of Serial Order

- There are three theories of how we retain order in memory:
  1. Chaining Theory
  2. Ordinal Theory
  3. Positional Theory
- Each theory has been formalised in computational models of serial recall

Chaining Theory

- According to **chaining theory**, order is stored by forming associations between each item and its neighbours, with stronger forward than backward associations
- The strength of the associations decreases gradually with the distance between study items
- Recall begins by cuing memory with the first list item, which in turn retrieves the second item, and so on
- Chained associations were the cornerstone of Ebbinghaus' (1885) classic work on memory for sequences
- Also central to several theories of serial recall (Lewandowsky & Murdock, 1989; Solway et al., 2012)

Chaining Theory



- Darker and thicker arrows indicate stronger associations formed between neighbouring list items
- Forward associations are stronger than backward associations

Chaining Theory

- One objection to chaining is how to get the chain started when the first item is not given as the cue to recall?
- Models resolve this problem by associating items to a “start marker” that can be used to kickstart the chaining process (e.g., Lewandowsky & Murdock, 1989; Solway et al., 2012)

Ordinal Theory

- According to **ordinal theory**, order is stored by the relative values of some continuous property of the items
- For example, Grossberg (1978) assumed that order is stored in a **primacy gradient** of item strengths, with the first item 'strongest' and the last item 'weakest'
- Order is retrieved by a repeated process of selecting the strongest item, and then temporarily suppressing it (**response suppression**) so as to recall the next strongest item, and so on
- This idea has been formalised in the primacy model of serial recall (Page & Norris, 1998)

Ordinal Theory

Cognitive Psychology

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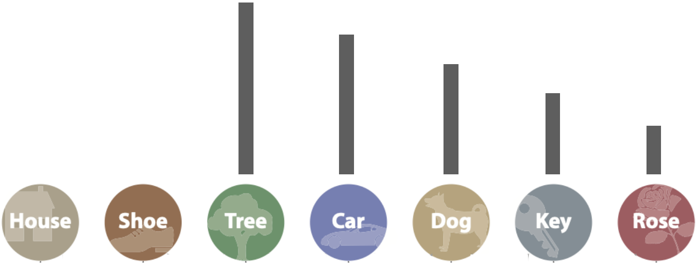
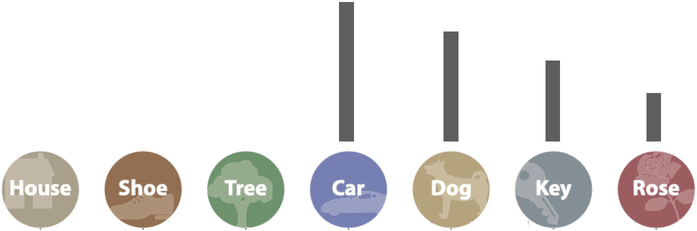
Ordinal Theory

Ordinal Theory



Ordinal Theory



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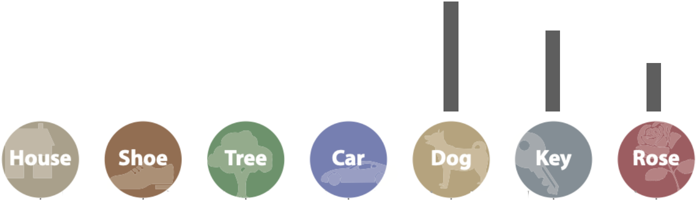


Ordinal Theory

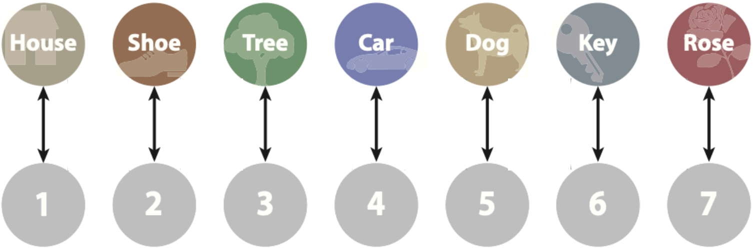
Ordinal Theory

Ordinal Theory

Positional Theory

- According to **positional theory**, order is stored by associating each item with a representation of its position in the list, known as a "position marker"
- The positional representations are approximate, rather than perfect
- Position markers for nearby positions overlap to a greater degree than for distant positions
- Order is retrieved by cuing memory with each of the position markers one by one
- This idea has been formalised in several models of serial recall (Burgess & Hitch, 1999; Brown et al., 2000; Henson, 1998)

Positional Theory



- Numbers indicate positional representations in memory, with 1 indicating the position of the first item and 7 indicating the position of the last item

Simulating Errors in Memory Models

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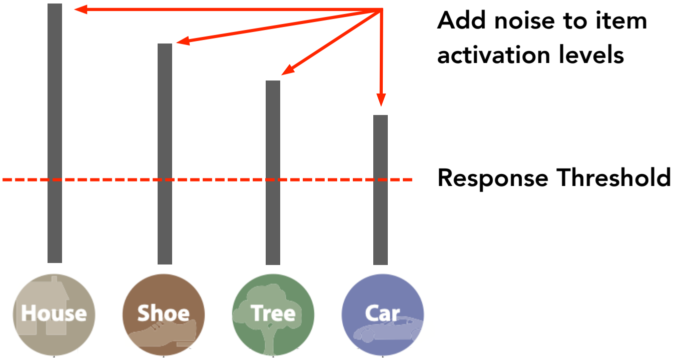

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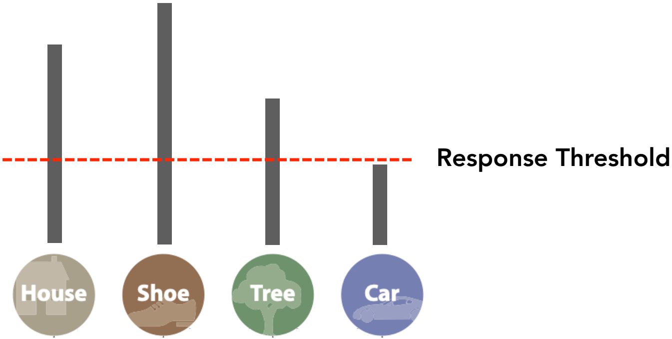

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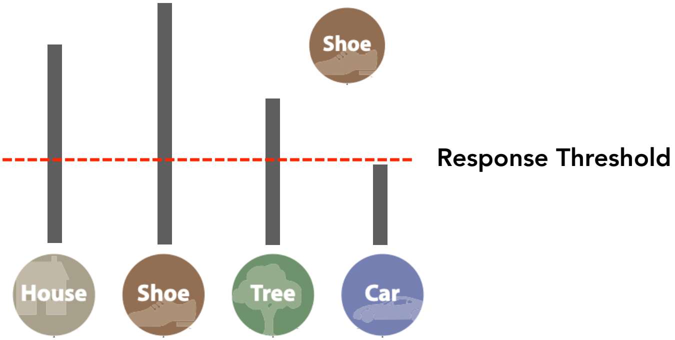

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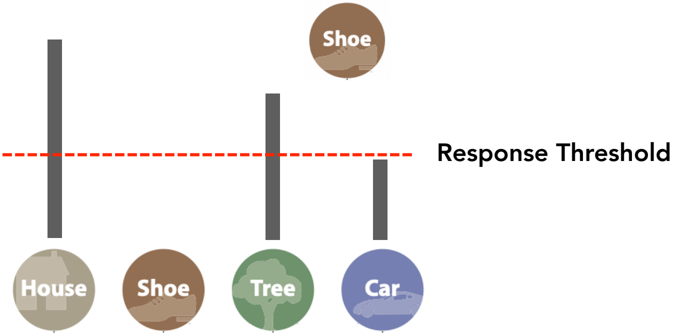

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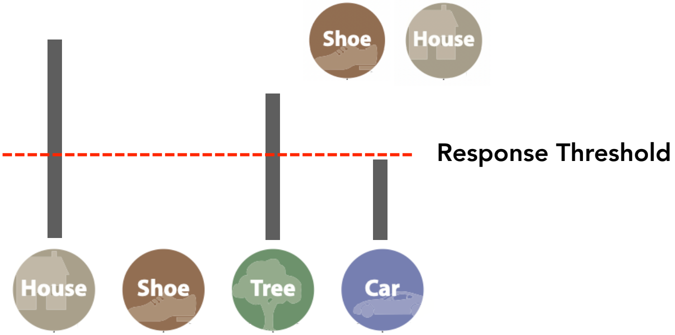

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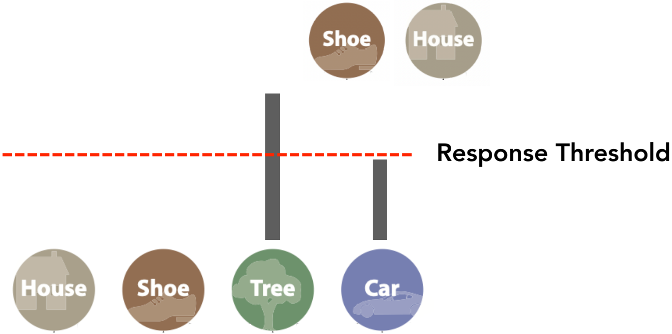

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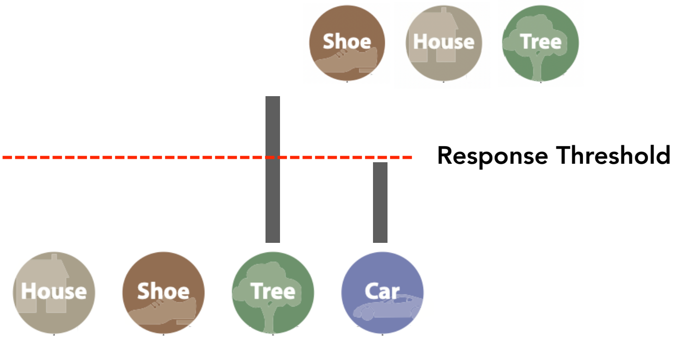

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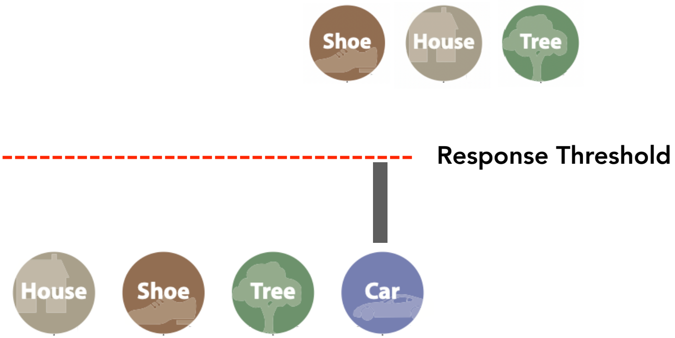

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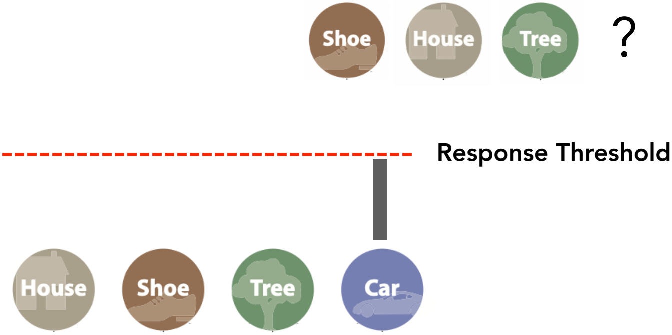


Critical Tests of Theories

- Any adequate theory of serial order in short-term memory must be able to explain the benchmark findings of serial recall reviewed previously:
  1. serial position effects
  2. list length effect
  3. error patterns
  4. grouping effects
  5. phonological similarity effect
- We next consider if and how each theory can explain these critical findings

Serial Position Curve

- According to chaining theory, recall of a given item i depends on successful recall of item $i-1$, which in turn depends on successful recall of item $i-2$ etc.
- The chaining model thus predicts recall performance will decrease from the beginning to the end of the list, producing a primacy effect
- The model does <u>not</u> predict a recency effect
- Recency can be generated by incorporating response suppression and/or retroactive interference (e.g., Lewandowsky & Murdock, 1989)

Serial Position Curve

- Ordinal models generate a primacy effect because the activation levels of items near the beginning of the list are more distinctive than toward the end of the list
- The recency effect arises due to response suppression
- As successive items are recalled and suppressed, the number of response competitors is gradually reduced
- The final item therefore encounters weak competition from neighbouring list items

Serial Position Curve

- In positional models, primacy and recency effects reflect "edge effects"
- There are less opportunities for items near the beginning and end of a list to swap with neighbours, compared to middle items
- Some positional models incorporate a primacy gradient (e.g., in the strength of associations between items and position markers)
- This increases the primacy effect predicted by the model

List Length Effect

- Errors in chaining, ordinal, and positional models occur probabilistically on each item
- The greater the number of items, the greater the probability of at least one error
- The probability of successfully recalling the entire list thus declines with increasing length
- An additional effect in some ordinal and positional models is that longer lists are less robust
- For example, the activation gradient in the primacy model (Page & Norris, 1998) becomes shallower as list length increases, resulting in increased competition

Error Patterns: Transposition Errors

- Chaining, ordinal, and positional models all predict a locality constraint
- In chaining models, cueing memory with a given item will activate neighbouring list items based on their degree of association with that item
- Near-neighbours will have strong associations and will compete strongly; distant-neighbours will have weak associations and will compete weakly
- The frequency of transpositions will decrease with increasing distance from the correct position

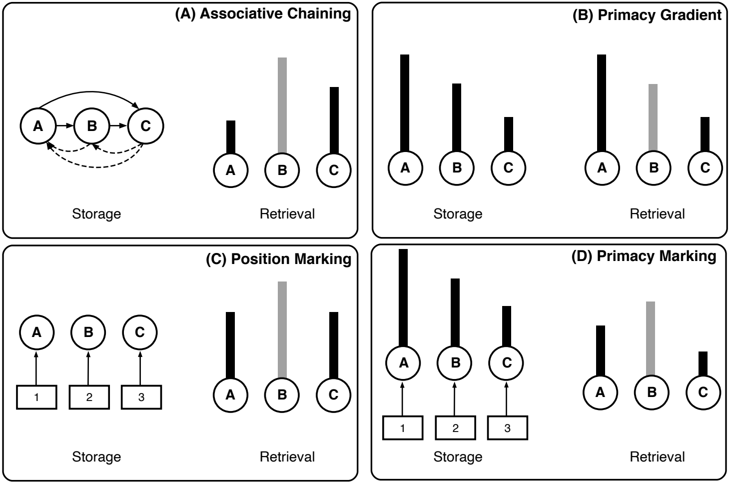
Error Patterns: Transposition Errors

- In ordinal models, the primacy gradient means the difference in activation level between items is smallest for those at neighbouring positions
- An item is thus more likely to exchange position with a nearby item than a distant item
- In positional models, list items are activated in memory based on the similarity between the position marker being used to cue memory, and the position marker items were associated with at study
- Since the position markers for items at nearby positions are more similar than those for items at distant positions, near-neighbour transpositions will be most frequent

Transposition Errors: Sequential Dependencies (Farrell et al., 2013)

- Recall that transpositions have a specific pattern of sequential dependency
- Suppose an item is recalled one position before its correct position (i.e., recalling B ... in response to the list A B C D)
- What happens at the position following the initial error?
  1. the error can be followed by report of the first item (i.e., B A ...), an error known as a **fill-in**, or
  2. it can be followed by report of the third item (i.e., B C ...), an error known as **infill**
- Fill-in errors are known to be roughly twice as frequent as infill errors (Farrell et al., 2013)

Error Patterns: Sequential Dependencies



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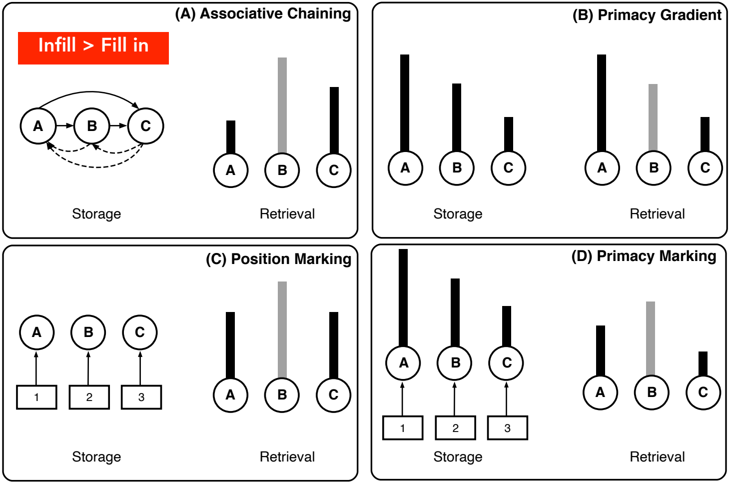

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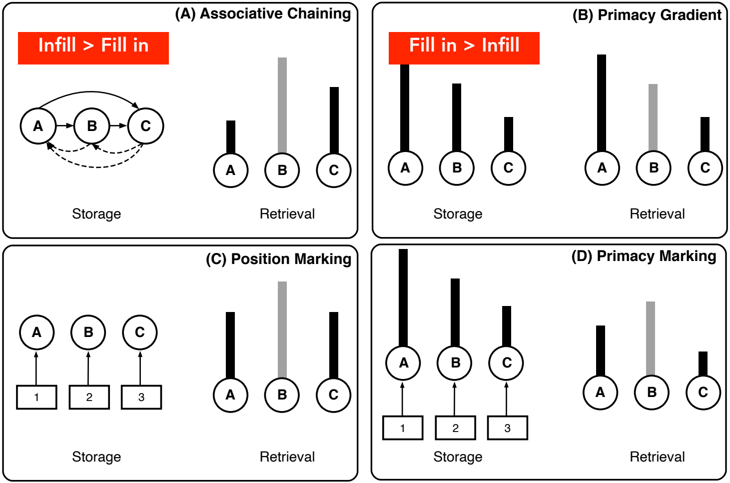

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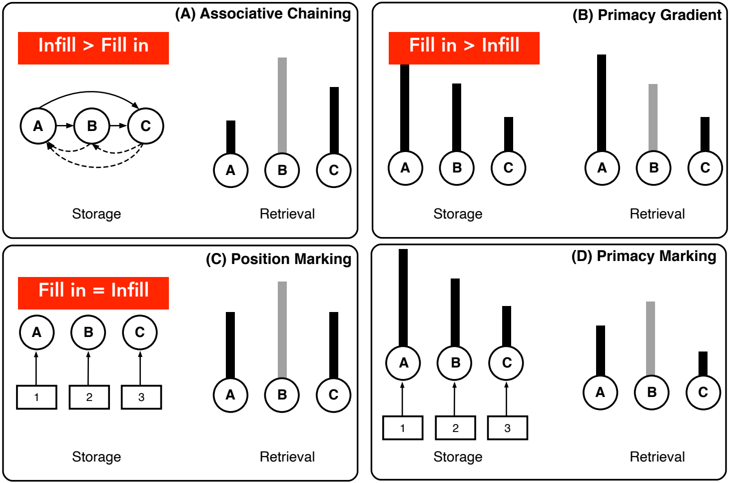
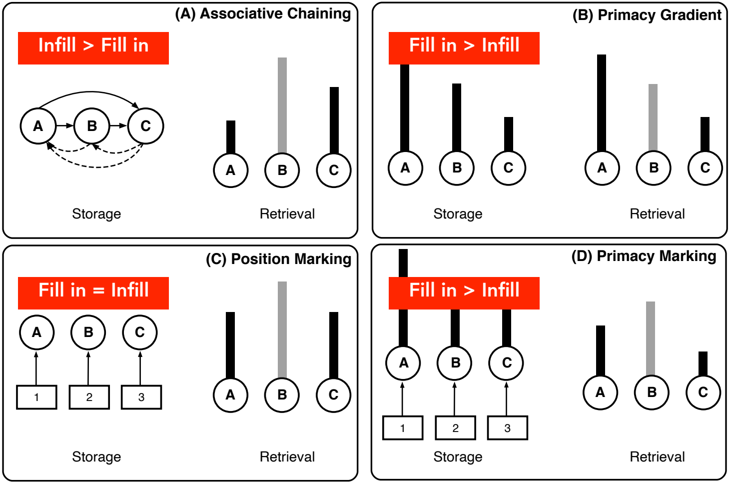


Error Patterns: Sequential Dependencies



Error Patterns: Intrusion Errors

- Intrusion errors arise in chaining, ordinal, and positional models because extra-list items are activated weakly at recall
- Occasionally an item not on the study list will be recalled when its activation exceeds that of list items
- Intrusions are problematic for chaining models
- An intruding item results in loss of the retrieval cues for the remaining list items

Error Patterns: Intrusion Errors

- Ordinal models predict intrusions will increase with output position, consistent with the data
- Extra-list items are activated weakly, meaning they will compete more strongly with list items toward the end of recall
- A purely positional model would predict a similar distribution of intrusions throughout recall
- A positional model incorporating a primacy gradient captures the increase in intrusions with output position

Error Patterns: Protrusion Errors

- Positional models can explain protrusion errors
- Different lists are encoded and retrieved using the same set of position markers
- The associations between items and position markers from prior lists ‘linger’ with the associations for the current list
- Cuing memory with the position marker for a given position will activate current, as well as prior, list items in memory
- The item on the prior list occurring in the same position as the target item being cued on the current list will offer the strongest competition of these prior-list items

Error Patterns: Protrusion Errors

- Protrusion errors are an important source of evidence for positional models of serial recall
- Neither chaining models nor ordinal models can accommodate these errors

Error Patterns: Omission Errors

- Chaining, ordinal, and positional models explain omission errors by incorporating a response threshold
- An item's activation level must exceed the response threshold in order for it to be retrieved, otherwise an omission is triggered
- Ordinal models predict that omissions will increase across output position because later list items are more likely to drop below the response threshold
- A purely positional model would predict a similar distribution of omissions across serial positions
- Positional models that incorporate a primacy gradient correctly predict an increase in omissions with output position

Error Patterns: Omission Errors

- Omissions are problematic for chaining models because the retrieval cues for the remaining list items will be lost
- Failure to recall an item should trigger a cascade of subsequent omissions
- This is contrary to the empirical data; people are often able to recover from omissions by recalling the correct items at subsequent positions

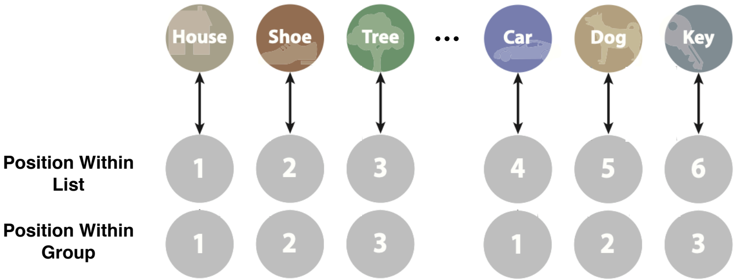
Error Patterns: Repetition Errors

- Chaining, ordinal, and positional models explain the infrequency of erroneous repetitions in terms of response suppression
- Items are suppressed in memory once they have been recalled, which reduces the likelihood they will be reported a second time
- Some models assume that this response suppression gradually wears off over time (decaying inhibition)
- This helps explain why repetitions are typically separated by 3–4 serial positions in the empirical data

Grouping Effects

- Grouping effects have been interpreted in terms of positional models of serial recall
- Positional models assume that grouped lists recruit two sets of position markers
- One set codes the position of items in the list overall (as in ungrouped lists)
- The second set codes the positions of items within groups

Grouping Effects



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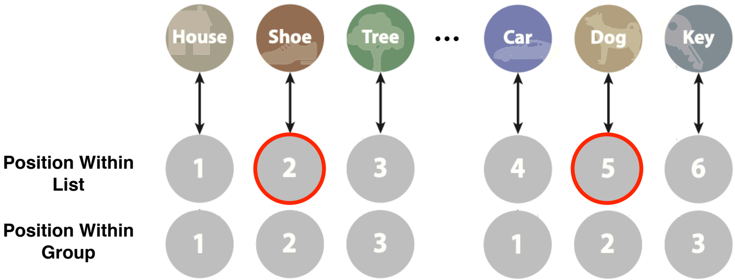
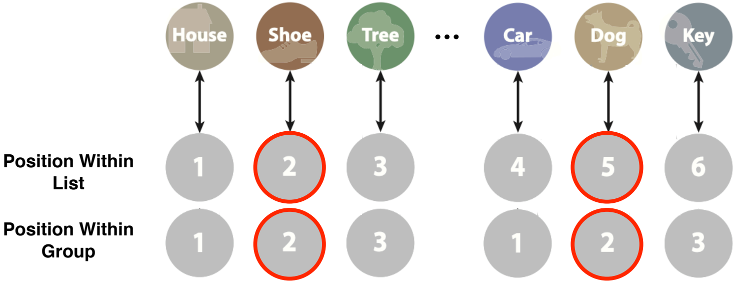


Grouping Effects



Grouping Effects

- The two sets of markers provide a more distinctive, two-dimensional coding of position
- Compared to ungrouped lists, the result is:
  1. a reduction in transposition errors overall
  2. mini within-group primacy and recency effects
  3. a tendency for items to migrate to corresponding positions in different groups (interpositions)
- These are all characteristic features of human performance

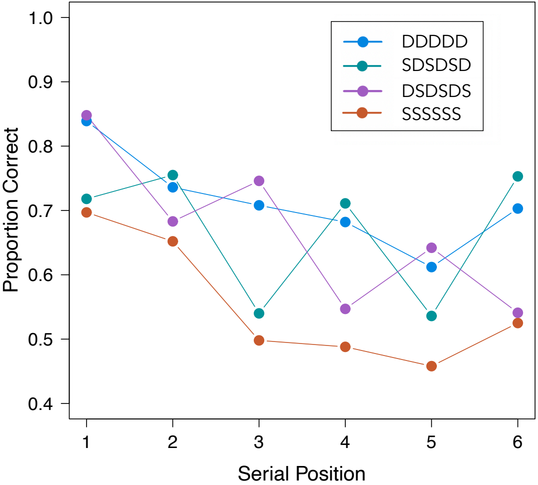
Grouping Effects

- Grouping effects are problematic for chaining and ordinal models
- It is possible to construct versions of these models that can explain the improvement in recall accuracy and mini within-group primacy and recency for grouped lists
- However, it is not possible to explain interposition errors without incorporating positional information
- Grouping effects have been used to argue against the sufficiency of both chaining theory and ordinal theory
- Such effects provide strong support for positional theory

Phonological Similarity Effect

- Chaining models assume that the phonological similarity effect arises because people chain along phonological representations of items
- The phonological similarity effect arises because each (similar) item is a non-unique recall cue for its successor
- For example, in the similar list *B D G T*, the correct cue for *D (B)* is phonologically similar to the cues for *G (D)* and *T (G)*
- Associative interference should lead to uncertainty for the response that should follow *B*
- In contrast, recall of *H* in the disimmilar list *H K Y R* should provide a much less ambiguous cue for *K*

Phonological Similarity Effect



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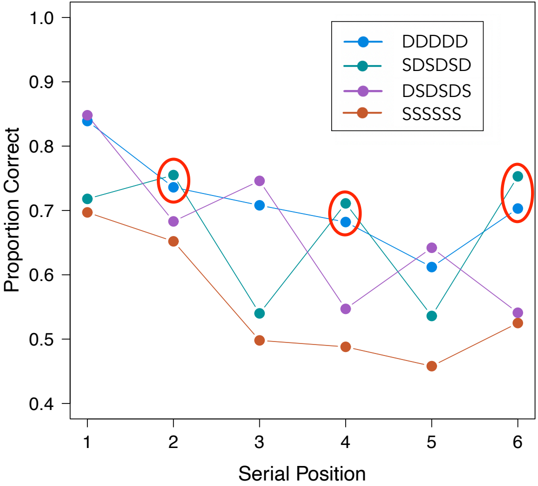

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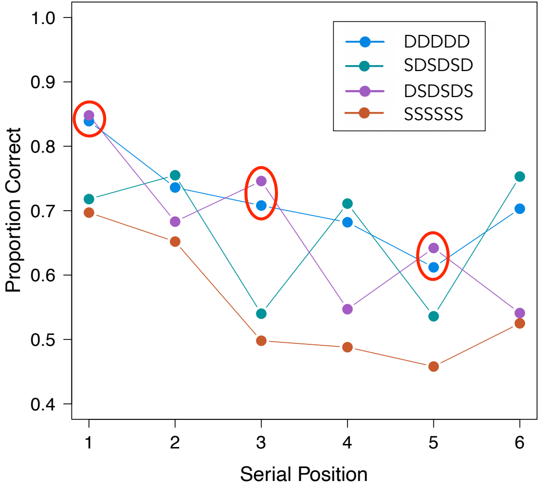
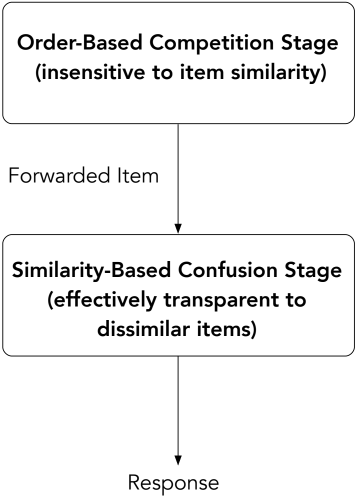


Phonological Similarity Effect

- Chaining makes an incorrect prediction about the kinds of errors on mixed lists
- Recall of the similar item T in the list $\underline{T}\ J\ \underline{B}\ M\ \underline{V}\ Q$ should lead to competition among the dissimilar items J M and Q
- Chaining models predict recall of dissimilar items on mixed lists will be worse than their twins on pure dissimilar lists
- This is contrary to the data and is strong evidence against chaining theory

Phonological Similarity Effect

- Ordinal and positional models explain phonological similarity effects by appealing to a two-stage retrieval mechanism
- In the first, *order-based competition stage*, items compete for selection based on their serial order
- An item selected in this stage is forwarded to a second *similarity-based competition stage*
- If the forwarded item is a phonologically similar item, then it competes with other similar items based on their degree of phonological similarity
- Dissimilar items essentially pass through this second stage unscathed



Phonological Similarity Effect

- This two-stage mechanism accounts for both pure and mixed-list phonological similarity effects
- For pure lists, similar lists are recalled less accurately than dissimilar lists because the items on such lists must undergo a second similarity-based competition, increasing the likelihood of errors
- For mixed lists, the similar items must also pass through this second stage, producing the ‘troughs’ in the sawtooth curves
- Dissimilar items pass through this second stage unhindered, producing the ‘peaks’ in the sawtooth curves
- The mechanism necessarily predicts dissimilar items on mixed lists will be recalled with the same level of accuracy as dissimilar items on pure dissimilar lists

Chaining Theory, Ordinal Theory, or Positional Theory?

Benchmark	Chaining Theory	Ordinal Theory	Positional Theory
Serial position curve	✓	✓	✓
List length effect	✓	✓	✓
Locality constraint	✓	✓	✓
Fill-in	✗	✗	✓
Intrusions	✗	✓	✓
Protrusions	✗	✗	✓
Omissions	✗	✓	✓
Repetitions	✓	✓	✓
Grouping effects	✗	✗	✓
Phonological similarity effect (pure lists)	✓	✓	✓
Phonological similarity effect (mixed lists)	✗	✓	✓

Conclusion:

- Order information in short-term memory is coded using positional information

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Grouping effects	✗	✗	✓
Phonological similarity effect (pure lists)	✓	✓	✓
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Conclusion:

- Order information in short-term memory is coded using positional information

Recommended Reading

Hurlstone, M. J. (2021, in press). Serial recall. Invited book chapter contribution to Kahana, M., and Wagner, A. *The Oxford Handbook of Human Memory* (Oxford University Press). `https://mark-hurlstone.github.io/H.21.OHHM.pdf`

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