Characterizing the interaction of temporal and semantic information in categorized memory search

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Overview

- Human memory search exhibits strong influences from temporal and semantic information.
- Free recall research has characterized these effects individually, but few studies have examined how they interact to bind together, or segment, individual events into meaningful episodes.
- Manipulating the level of inter-item distraction at study, while keeping the timing consistent, disrupts the temporal and semantic organization of recall.
- With minimal distraction, items can be bound into clusters based on temporal proximity or semantic relatedness. Heavy distraction causes a disintegration of this structure and a drop in performance.
- Task demands such as continual distraction mitigate the event structure of items at recall.

Experimental Design

Continual distraction in categorized free recall n=82

C C C L L L O O O L L L C C C O O O L L L C C C O O O

1 2 3 4 5 6… … 26 27

stimuli

C: celebrity, L: landmark, O: object (*Polyn et al., 2005*)

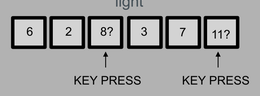
27 items per list, presented visually

9 triplets of same-category items

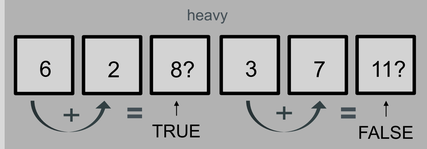
free recall
90s to verbally recall items from the list in any order

inter-item distraction

light



heavy



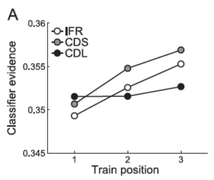
light distraction: vigilance task.
key press when you see '?'

heavy distraction: mental arithmetic.
sum of the previous integers (T/F)

length of distraction period ranged from 3-7s (mean=5s) to allow for single trial analysis

visual presentation and motor response were identical across the two distraction conditions

Theory



- Previous studies have found that inter-item distraction does not affect temporal organization in free recall paradigms
- Morton et al., (2013) found a 'neural integration' effect in scalp EEG data; patterns become increasingly category-specific with sequential study of same-category items
- Adding a time-varying distraction task, Morton & Polyn (2017) then found that longer inter-item distraction disrupts this neural integration of semantic information
- We manipulate the intensity, rather than the length, of distraction to characterize effects on recall organization

Temporal dynamics of recall

Retrieved-context theory applied to categorized FR

Context layer: constructs a temporal representation of on-going experience. Context gradually drifts over time, becoming increasingly dissimilar from current events

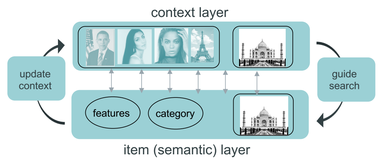
Hebbian learning rule: associates context and semantic space

- temporal context becomes a retrieval cue to guide search
- recalling an item reactivates the state of context at encoding
- this increases the likelihood of recalling neighboring items next

Integration: during learning, new items are pushed into the context layer where they *integrate* with existing representations to create a running average of recently studied items

According to classic temporal context models (TCMs), distraction task information will be integrated into temporal context, but should not affect the degree of temporal organization

(Howard & Kahana., 2002; Sederberg et al., 2008; Polyn et al., 2009)

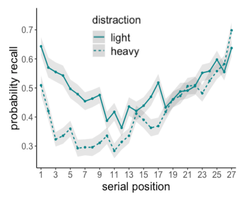


Semantic layer: perceptual features of stimuli activate conceptual representations in a pre-experimental semantic space.

existing semantic knowledge interacts with event structure to bias recall based on the similarity of items

Temporal organization is disrupted

Serial position curve: *the probability that an item is recalled, based on it's position in the study list*

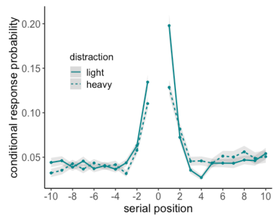


- Performance decrease; fewer items are recalled when studied with heavy distraction
- Primacy effect; the first items in a list are likely to be recalled with minimal distraction, and are more vulnerable to drop out of recall with distraction
- Intensity of distraction might modify context at an accelerated rate, causing items at the start of the list to be dissimilar from context at the time of test and lose their primacy advantage

Contiguity

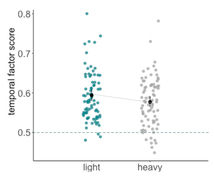
Contiguity effect: *items studied near one another are more likely to be recalled together.*

- The contiguity effect becomes weaker when items are encoded with a more demanding inter-item distraction
- TCMs propose that adjacent items are bound into a compound representation
- Our data show that nearby items are less likely to be clustered at recall with heavy distraction, suggesting that the inter-item task interferes with temporal binding.
- Distraction disturbs a cognitive control process that utilizes the temporal structure of a study list – this challenges the retrieved context theory of an internally guided memory search



Event structure

temporal factor score: *ranks the absolute value of actual : possible transitions. scores > 0.5 indicate temporal clustering*

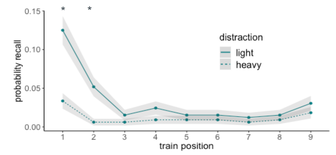


No difference in temporal factor between conditions suggests that the decrease in clustering is isolated to immediate lags; nearby items that form an episode

We looked to see if train structure (i.e. triplet of same-category items) was preserved in recall

- with light distraction, the probability of recalling the first train intact was ~12.5%
- train preservation reliably decreased in the first 6 items with heavy distraction
- train disintegration and impaired performance are concentrated at the start of the list

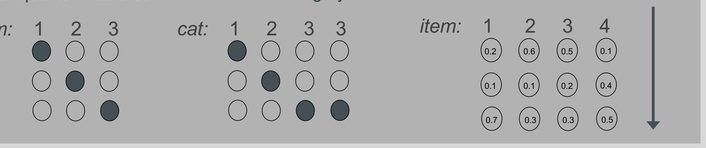
- We propose that the intense distraction task disrupts a strategic process that partitions the items into discrete events, or episodes (Zacks & Swallow., 2007)
- Lacking segmented events, studied items have less context relevant inter-associations



Semantic Organization

We can model pre-experimental semantic representations in 3 ways

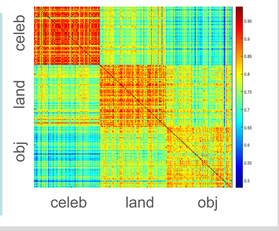
1. unique item features
2. coarse category features
3. distributional semantic features



semantic vector space

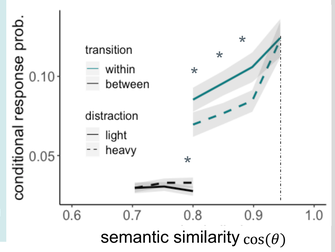
We create a stimulus space populated with unique 300-d vectors, derived from Wikipedia text, that capture the features of each item (https://github.com/prestonlab/wiki2vec)

Distance metrics can characterize the similarity of items – a pairwise cosine similarity matrix of our stimuli reveals clear category boundaries (warmer colors indicate semantic similarity)

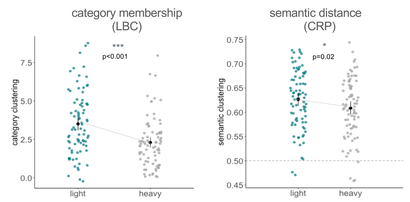


semantic CRP (within v between category transitions)

- Participants take advantage of semantic relatedness during memory search:
  - same category items are more likely to be recalled together
  - these within-category transitions are impaired with heavy distraction
- Interestingly, items that are highly semantically related are spared this impairment and are recalled together regardless of distraction
- Transitions between-category show a small, but statistically reliable, increase with heavy distraction *for highly semantically similar items*
- Distraction disturbs temporal binding at encoding, thereby increasing the likelihood of a between category recall



Semantic organization is disrupted



clustering scores

- Distraction decreases semantic clustering at the category level and, to a lesser extent, the item (distributional) level
- In order to capture the diminished semantic structure, a model of recall with distraction should consider the interaction of category and item representations
- Adding category labels to a retrieval model emphasizes category commonality, whereas unique feature vectors emphasize item distinctiveness. Organization in categorized recall is best characterized by this compound representation

Conclusions

- Completing a cognitively demanding task during learning decreases recall performance, perhaps by disturbing a control mechanism that takes advantage of list structure to create events
- Pre-experimental semantic information binds items together based on multiple feature levels. Future studies should consider the effect of task demands on item, category and distributional feature representations
- Memory search is best characterized as an interaction between semantic & episodic memory. Existing knowledge is flexibly used to construct an episode
- To understand these nuances, retrieved-context models could include an executive function that (i) is disrupted with distraction and (ii) captures the interplay of conceptual and event information

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