Semantic and visual similarity guide visual search for words and numbers

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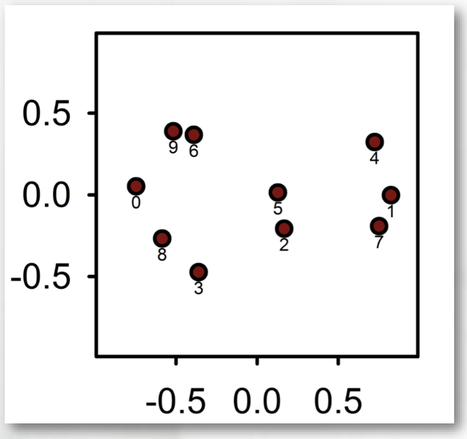
- - - DOES SEMANTIC-RELATEDNESS IMPACT VISUAL SEARCH? - - -

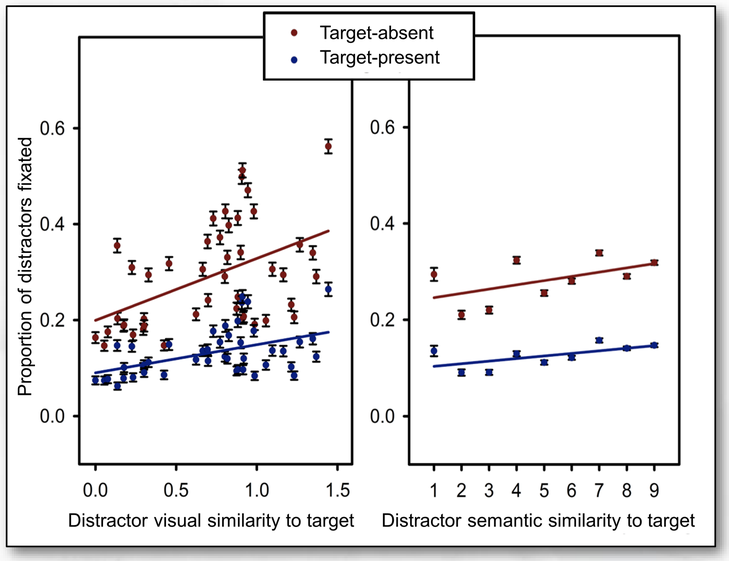
- When people look for things in their environment, they guide their attention using target "templates" – mental representations of the to-be-located item(s), stored in visual working memory (Wolfe et al., 2004).
- Templates are used to 1) guide attention to regions of a scene that share features with the target and 2) to compare incoming visual input to a representation of the target in memory (Hout & Goldinger, 2014).
- Is it possible that related (perhaps non-visual) information may be activated by template use (e.g., through spreading activation), drawing our attention to items that share semantic similarity with the target, or making it harder to reject such things as distractors?

- - - SEARCH FOR NUMBERS - - -

- With complex stimuli, teasing apart visual and semantic similarity is quite difficult.
- Numbers provide a domain in which semantic similarity is inherently controlled, and can therefore be quantified (i.e., via numerical distance; Schwarz & Eiselt, 2012).
- We measured the visual similarity of numbers 0-9 using multidimensional scaling (MDS), which is a statistical tool by which researchers can obtain quantitative estimates of similarity among a group of items (Hout, Papesh, & Goldinger, 2012). Participants rated the similarity of the numbers using the spatial arrangement method (*SpAM;* Hout, Goldinger & Ferguson, 2013) of MDS.
- Other participants searched for a target digit amongst other digits (e.g., 0 amongst 1-9), making target-absent vs. target-present responses. N = 30.
- Eye movements were recorded using an Eyelink 1000. Linear mixed effects models were used to analyze viewing behavior as a function of visual similarity (indexed via distance in MDS space) and semantic similarity (indexed by numerical distance).



Two-dimensional MDS solution for digit stimuli. The pattern closely mirrors data from Shepard et al. (1975).



Proportion of distractor objects fixated as a function of the visual similarity (left panel) and semantic similarity (right panel) to the target object, for both target-present (blue) and target-absent (red) trials.

RESULTS

- Fixation of distractors was guided by both visual and semantic similarity.
- Visual similarity played a larger role than semantic similarity in guiding search.
- Effects of visual similarity were stronger on target-absent than target-present trials.
- See Godwin, Hout, & Menneer, *PB&R* 2014 for full report.

- - - WORD SEARCH- - -

- Using simple stimuli, we've shown that attention can be drawn to items that share visual and semantic similarity to the target.
- New questions: 1) do the findings scale up to more complex stimuli that require foveation for identification? And 2) if so, are object identification processes affected by semantic similarity?
- E.g., when searching a website for information (see Fitzsimmons poster #4177 and Drieghe talk Saturday PM), does semantic information play a role in information processing?

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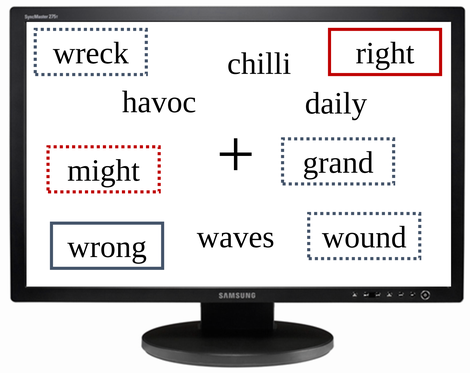
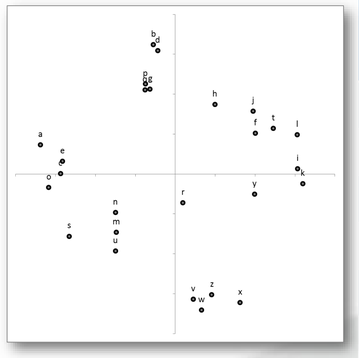
- People looked for a target word among distractors, making present/absent decisions. All words were 4 or 5 letters long (held constant within trials).
- Eye movements recorded, as before. N = 22. Generalized linear models were used to analyze viewing behavior.
- Distractors included 1) a semantically related word, as well as 2) words that were visually similar or dissimilar to the target, and 3) words that were visually similar or dissimilar to the related word.
- Semantic relatedness was determined using the University of South Florida Free Association Norms; (E.g., "BOOK ???" → "read").



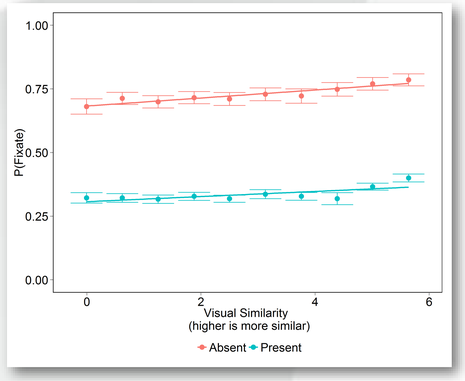
Sample visual search display (borders added for demonstrative purposes). The target is bordered in blue, and the semantically related word in red. Words that are visually similar to the target are shown in broken blue borders, and word visually similar to the related word are shown in broken red borders. Visually dissimilar words have no borders.



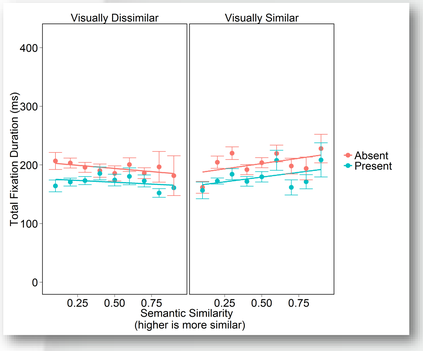
MDS solution for letter stimuli, collapsed across two dimensions.

Target: "wrong"	Visually similar: "wreck"	Visually dissimilar: "daily"
w	w (0.00)	d (1.32)
r	r (0.00)	a (0.90)
o	e (0.16)	i (1.30)
n	c (0.37)	l (1.00)
g	k (0.92)	y (0.88)
Total Distance	1.45	5.40

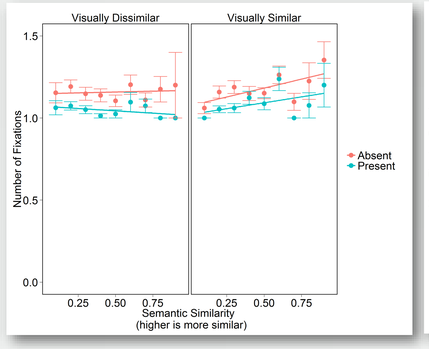
- Visual similarity was measured using MDS; participants rated the similarity of all letters of the alphabet using SpAM.
- Visual similarity between Word 1 and Word 2 involved taking the distance in MDS space between each letter (in order), then summing the distances. Larger distance → more dissimilar.



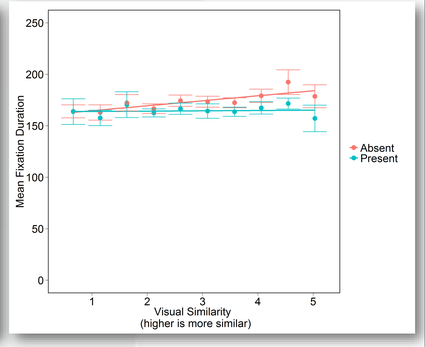
Probability of fixating a word (all words considered), plotted as a function of target presence and visual similarity.



Total time fixating the semantically related word, plotted as a function of target presence, semantic similarity and visual similarity.



Number of fixations on the semantically related word, plotted as a function of target presence, semantic similarity and visual similarity.



Average fixation duration on the semantically related word, plotted as a function of target presence, and visual similarity.

RESULTS

- Probability of fixating: Considering all words, visual similarity has a clear effect, increasing the probability of fixating words that are visually similar to the target.
- Total time fixating: Looking at the semantically related words, we find that both semantic and visual similarity increase time spent looking at the word, with an interaction between the two.
- Number of fixations: Focusing on the number of fixations as one part of the total time, we see that semantic similarity increases the number of fixations on a word, again with an interaction between semantic/visual similarity.
- Average fixation duration: Focusing on the fixation duration as another part of the total time, it is clear that visual similarity increases time spent looking at a word on each visit, but this is not true of semantic similarity.

- - - CONCLUSIONS - - -

- Search for numbers and words is influenced by both visual and semantic similarity.
- We found evidence that visual and semantic factors not only affect attentional guidance, but also word identification, using measures such as time-based processes and the number of fixations. This contributes to the growing literature on semantic influences in visual search.
- The conjunction of MDS and eye-tracking provide a useful tool for teasing apart vision and semantics, and offer a useful alternative to existing methods (e.g., Levenstein distance).

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