# UC Merced

**Proceedings of the Annual Meeting of the Cognitive Science Society**

**Title**

Looking for the Cat and Seeing the Dog:Using Visual Search to Study Semantic Knowledge in Children

**Permalink**

https://escholarship.org/uc/item/9jj604j3

**Journal**

Proceedings of the Annual Meeting of the Cognitive Science Society, 39(0)

**Authors**

Vales, Catarina
Unger, Layla
Fisher, Anna V.

**Publication Date**

2017

Peer reviewed

# Looking for the Cat and Seeing the Dog:
# Using Visual Search to Study Semantic Knowledge in Children

**Catarina Vales (cvales@andrew.cmu.edu)**
**Layla Unger (lunger@andrew.cmu.edu)**
**Anna V. Fisher (fisher49@andrew.cmu.edu)**
Carnegie Mellon University, Department of Psychology, 5000 Forbes Avenue
Pittsburgh, PA 15214 USA

## Abstract

Semantic knowledge influences various higher-order cognitive processes; therefore, it is important to understand how it changes with development. The Match-to-Sample task is perhaps the most common paradigm for studying changes in semantic knowledge over development, yet this paradigm has a number of limitations. Here we provide initial evidence validating a Visual Search paradigm as a measure of semantic knowledge in preschoolers, and discuss the potential of this paradigm to address the limitations posed by the Match-to-Sample task to study semantic knowledge development.

**Keywords:** semantic knowledge; visual attention; visual search; match-to-sample; language; children.

## Introduction

Knowledge about the world supports efficient behavior. For example, knowing that cats are often playful and have sharp claws makes one careful when playing with a cat, and knowing that light bulbs generate light makes one likely to check the light bulb if a lamp stops working. This knowledge about objects, facts, and concepts (Clark, 1973) is thought to be represented in a semantic network that links entities by multiple meaningful relations (McClelland & Rogers, 2003). Structured semantic knowledge influences multiple cognitive processes, including memory, reasoning, word learning, and visual attention (Bower et al., 1969; Chi et al., 1981; Moores et al., 2003; Roediger & McDermott, 1995; Xu & Tenenbaum, 2007), and individual differences in semantic knowledge have been putatively related to the ability to make inferences about novel instances (Coley, et al., 2004; Gobbo & Chi, 1986; Fisher, 2015).

### Developmental changes in semantic knowledge

As semantic knowledge plays an important role in supporting efficient behavior, there is a large literature investigating what aspects of semantic knowledge change over development to give rise to mature, adult-like behavior. One of the most widely used tasks to study the development of semantic knowledge is the Match-to-Sample task; in this task, participants are shown a target object (e.g. *chicken*) and asked to match it with one of two options – often a thematic match (an item that is likely to co-occur with the target item, such as *pig*) and a taxonomic match (an item that belongs to the same stable category of items that share intrinsic properties, such as *eagle*). Research using this task has documented marked age-related changes starting in the

preschool years in preferences for matching items on the basis of different types of relations (Smiley & Brown, 1979; Walsh, et al., 1993). However, the Match-to-Sample task presents two main limitations to study *developmental* changes in semantic knowledge. First, this task cannot be used with young children who are unable to follow verbal instructions and indicate their choices. Prior research examining semantic knowledge development in infants and toddlers has used other tasks (e.g. Arias-Trejo & Plunkett, 2009; Chow et al., 2017), which may result in confounding developmental changes and task demands. Second, because the Match-to-Sample task requires participants to make explicit judgments about the items, performance in this task might stem not only from knowledge of semantic relatedness but also from other deliberative processes. Indeed, past research with children has shown that performance in the Match-to-Sample task is modulated by the wording of instructions (e.g. Waxman & Namy, 1997), suggesting that interpreting the pragmatics of the task plays a role in which objects children select. In sum, this task is not ideally suited to study changes in semantic knowledge.

Priming procedures have been used to bypass the limitations of the Match-to-Sample task in adults; however, traditional priming paradigms are difficult to implement with young children. Although several studies have used semantic priming paradigms in infants using looking behavior measures (vs. manual response times) (e.g., Arias-Trejo & Plunkett, 2009), paradigms developed for infants are often not suitable for older children who are not content to inspect visual displays in the absence of an overt task. Below we suggest that a measure of visual attention has the potential to address the limitations outlined above and be used to study semantic knowledge over the lifespan.

### The Visual Search paradigm

Research with adults has used visual attention measures to study knowledge associated with concepts (e.g. Huettig et al., 2011). In these studies, participants are cued about an upcoming target (e.g. by hearing a word or a sentence) and asked to locate the target in a cluttered display. Participants' response times to detect the target (Moores et al., 2003) or their gaze while scanning the array (Huettig & Altmann, 2005; Mirman & Magnuson, 2009) are taken as a proxy for the co-activation of concepts related to the target.

A Visual Search paradigm has two main advantages for studying the development of semantic knowledge. First,

visual search tasks have been successfully implemented across the lifespan (Gerhardstein, & Rovee-Collier, 2002; Vales & Smith, 2015), in children with developmental disorders (Kaldy et al., 2011), and with varying degrees of language knowledge (Vales & Smith, 2017). Thus, a Visual Search paradigm is well suited to studying developmental changes in semantic knowledge, reducing differences in task demands from using different tasks with different populations. Second, the Visual Search task allows semantic knowledge to be measured by manipulating the distractors present in the array; because participants do not make explicit judgements about these related distractors, deliberative processes are greatly reduced (see Chun & Jiang, 1998 for evidence that people are often unaware of experimental manipulations in the visual array). In sum, the Visual Search task is a good candidate to address the limitations of the Match-to-Sample task outlined above.

### The current study

In this study, we seek initial evidence that a Visual Search paradigm can provide estimates of semantic relatedness that are broadly consistent with the estimates from tasks used in prior research. If this is the case, then items judged as more strongly related in a Match-to-Sample task should also more strongly influence performance in a Visual Search task. To this end, we used the Match-to-Sample task to select pairs of target-distractor items. Each potential distractor was tested against a foil that we identified as more distantly related to the target. Measuring the rate at which children chose each distractor versus the foil allowed us to calibrate two distractors for each target, one *strongly-* and one *weakly-related*. While the Match-to-Sample procedure suffers from low resolution to detect graded responses, as it allows only binary judgements on each trial, it should still provide a coarse measure of semantic relatedness. We then tested the effect of target-distractor strength in a Visual Search task by asking children to indicate if a target was present in an array of distractors. Across trials, we manipulated the presence of the related distractors; performance in the critical trials in which a related distractor was present was compared with performance in baseline trials in which the related distractors were replaced by items unrelated to the target object. The degree to which children performed more poorly in the presence versus absence of a related distractor was used as the measure of the strength of the perceived relation. As in previous studies with adults and infants (e.g. Chow et al., 2017; Moores et al., 2003), we focused our analyses on target-absent trials, because participants' attention to the target on target-present trials leaves little room for related distractors to influence performance. Target-present trials were included to ensure that children were completing the target identification task.

Prior work using the Match-to-Sample task suggests that children under the age of four are unlikely to consistently select an item related to the target if the foil is a strong competitor (e.g. a visually similar item; Godwin & Fisher, 2015). As such, we recruited 4 and 5-year-old children, as this is the youngest age group that we can confidently expect to complete the Match-to-Sample task and thus provide reliable relatedness judgements.

## Methods

We first describe the Match-to-Sample task used to select pairs of items, and report the items selected. Next, we describe the Visual Search paradigm used to test the hypothesis that items judged as more similar in the Match-to-Sample task should also more strongly influence performance in the Visual Search task.

### Stimuli Selection: Match-to-sample task

To select pairs of items with varying strength, we conducted a calibration study with 16 children ($M_{age}$=4.9 years, range=4.0-5.9, 6 females); children were recruited from local preschools and from a university-affiliated laboratory school in Pittsburgh, PA and tested in a quiet location.

We selected 10 target objects that were likely to be recognized by young children from a prior study investigating the role of semantic relations in a Visual Search task (Moores et al., 2003). For each target, we selected four related items to be tested in the Match-to-Sample task with the goal of selecting two related items (one strong relation and one weaker relation); the relation strength between each target and each related item was tested in the presence of the same foil, judged by the authors to be a plausible competitor. For example, to test the strength between *cat* and the items *bear*, *bird*, *dog*, and *mouse*, participants were presented with the following triads: *cat-bear-butterfly*, *cat-bird-butterfly*, *cat-dog-butterfly*, *cat-mouse-butterfly*. Two testing sets were created by randomly selecting two of the four triads for each target. Each participant completed one of the sets, for a total of 20 test trials; the order of the trials was randomly determined for each subject, with the constraint that the same target was not presented on consecutive trials. The target was displayed at the top center of a computer screen, and followed by the presentation of the two options (related item and foil); these were presented on the left and right bottom of the screen, with side counterbalanced across trials.

To ensure that children understood the task and were not arbitrarily selecting items, five "catch" trials were randomly placed amid the test trials. These catch triads were intended to introduce no conflict and included items not used in the test trials (e.g. *cherries-apple-stapler*). On average, children selected the related object on 95% (*SD*=0.12) of the catch trials, suggesting that they understood the task (one additional child failed to complete at least 3 out of the 5 catch trials correctly and was not included in the sample). Additionally, because the Match-to-Sample task presented the same foil for each target (and thus children saw the same *target-X-foil* triad more than once), we checked that children were not learning to reject the foil for each target by presenting a block of 10 "control" trials after the experimental trials. In these control triads, the foil used on the test trials was presented against an item judged to be

unrelated to the target (e.g. *cat-butterfly-watch*). If children were learning to reject the foil over the course of the experimental trials, they should select the non-foil item (the *watch* in this example); on the other hand, if children were responding to each triad by considering how the items are related, they should select the item that is more strongly related to the target within each triad, even if previously they have not selected that item (the *butterfly* in the example above). On average, children selected the related item (the *butterfly* in this example) on 81% (*SD*=0.24) of the control trials; this suggests that children were considering how the items were related within each trial.

For each target, we selected two related items that varied in the degree of semantic relatedness, a *strongly-related* item (selected by most children) and a *weakly-related* item (selected at a lower rate, at or above chance). Two targets items (*banana* and *cow*) failed to produce relations that satisfied these conditions and were not used in the Visual Search task. Table 1 presents the eight sets of items consisting of a target, strongly-related item, and weakly-related item to be used in the Visual Search task and the proportion of trials in which each related item was selected in the Match-to-Sample task. On average, strongly-related items were selected on 94% (*SD*=0.09) of the trials and weakly-related items were selected on 61% (*SD*=0.10) of the trials in the Match-to-Sample task, $t(14)$=6.97, $p$<0.001. These sets of items were used to create 16 target-related match pairs for the Visual Search task.

Table 1: Proportion of trials each related item was selected in the Match-to-Sample task.

| Target | Strongly-related | | Weakly-related | |
|---|---|---|---|---|
| *bike* | *skateboard* | 0.86 | *train* | 0.71 |
| *carrots* | *rabbit* | 0.78 | *horse* | 0.58 |
| *cat* | *dog* | 1.00 | *mouse* | 0.67 |
| *chair* | *table* | 0.89 | *bed* | 0.57 |
| *chicken* | *turkey* | 1.00 | *eagle* | 0.55 |
| *drum* | *guitar* | 1.00 | *piano* | 0.57 |
| *foot* | *shoe* | 1.00 | *glove* | 0.77 |
| *lamp* | *flashlight* | 1.00 | *candle* | 0.44 |

## Visual search task

**Participants.** Twenty-four children (*M*~age~=4.8 years, range=4.0-5.8, 12 females) were recruited from a university-affiliated laboratory school in Pittsburgh, PA and tested in a quiet location; these children had not participated in the calibration study. One additional child was recruited but not included in the final sample due to computer malfunction. Children had no known developmental or visual impairments, and English was their only or main language.

**Apparatus and Stimuli.** Stimuli were presented on a 15.6" touchscreen laptop and responses (accuracy and latency) were recorded using E-Prime (PST, Pittsburgh, PA). To prevent color information from guiding participants' search,

each image was recolored in sepia; recolored images were rendered in a 200 x 200 pixel area on a white background. The audio files used to present the spoken names of the targets were recorded by a female native speaker of English.

**Design and Procedure.** There were six trial types, resulting from all combinations of target presence (present/absent) and related distractor presence (strong present, weak present, related absent), with equal occurrence of each trial type. On each trial, children saw four objects, one on each quadrant of the screen and all equally distant from the center of the screen. Depending on the trial, the four objects were combinations of target, related distractor, and random distractor objects. The order of the test trials was randomly determined for each child, provided that the same target did not appear on consecutive trials. Across trials, the target and related distractors appeared equally often on the left and right side of the screen. A unique token of each concept was used on each trial; for example, each trial probing *cat* used a different token (see Figure 1 for examples).



Figure 1: Tokens used to instantiate the concept "cat".

Figure 2 shows the temporal order of events on each trial. A "fixation" slide encouraged the child to rest their hands on the table before the trial started (Fig. 2a); the experimenter ensured that the child had their hands down and was looking at the screen before starting a trial. The spoken name of the target (Fig. 2b) was then presented and followed by the search array (Fig. 2c); upon viewing the search array, children had to indicate if the target was present or absent by touching one of two buttons.
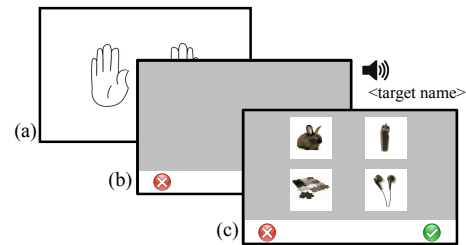


Figure 2: Visual Search, trial structure. The target (*carrots*) is absent and the strong distractor (*rabbit*) is present.

Children sat in front of the laptop and were told that the goal of the game was to look for pictures on the screen. They were first shown which buttons to touch ("Touch this button if you see the picture on the screen and this button if you do not see the picture on the screen"); the location of the two buttons was counterbalanced across participants. Children were asked to repeat the instructions ("Can you show me which button you touch if you do not see the picture on the screen?") and all children correctly repeated the instructions. Next, children completed 4 "warm-up" trials in which they were familiarized with putting their

hands down during the "fixation" slide, listening to the audio cue, and touching the appropriate button to indicate the target's presence or absence; feedback was provided and children were reminded of the instructions if necessary. Children then completed 48 test trials. The experimenter gave general encouragement throughout the task (e.g. "You are doing great") but did not provide explicit feedback. A short break was introduced every 16 trials during which children could stamp a progress chart.

## Results

To confirm that children were performing the task, we start by analyzing performance on target present trials. Next, we focus on target absent trials to test the hypothesis that items judged as more similar to the target in the Match-to-Sample task also more strongly influence performance in the Visual Search task. We used linear mixed models to analyze the effect of target-distractor relatedness on the time taken to indicate the target's absence (RT). Differently from a traditional analysis of variance, which requires data to be aggregated and incorrect trials to be excluded, a mixed model can include all data and take accuracy into account by modeling the data at the trial level. We included both subject and target item as random factors, that is, varying around a group mean; modeling both subject and target item as random effects is particularly important in experimental designs in which the two factors are fully crossed (Baayen, Davidson, & Bates, 2008; Jude, Westfall, & Kenny, 2012).

### Target present trials

Children correctly indicated the target's presence on 83% ($SD$=0.37) of these trials, suggesting they were trying to locate the target. No main effect of distractor strength on accuracy was found, $F(2,46)$=1.78, $p$=0.18.

### Target absent trials

Children correctly indicated the target's absence on 91% ($SD$=0.28) of these trials. This supports the conclusion from target present trials that children were searching for the target. However, there was a main effect of distractor strength on accuracy, $F(2,46)$=10.49, $p$<0.001, as participants were less accurate when the strongly-related distractor was present in the array ($M_{acc}$=0.84, $SD$=0.36) than when the weakly-related distractor was present in the array ($M_{acc}$=0.95, $SD$=0.22) or when all items in the array were unrelated to the target ($M_{acc}$=0.95, $SD$=0.21). Analyzing RT for correct trials only would exclude different amounts of data from each condition; instead, we include accuracy as a factor in the analyses below. The same pattern of results is found when we consider only correct trials.

Figure 3 depicts mean RT across the three types of trials. Relative to baseline trials (M=3.6s), children took over a second longer to judge the target's absence in the presence of a strongly-related distractor (*M*=4.7s), but only slightly longer in the presence of a weakly-related distractor (*M*=3.8s). To assess how the strength of the distractors influenced the ability to correctly indicate the target's absence, we implemented a linear mixed model using the lme4 package (Bates et al., 2015) in the R environment. We specified accuracy (correct, incorrect) and strength of the distractors (unrelated, weak, strong) as fixed effects, and subject and target item as random effects. The RT outcome variable was log-transformed. Wald *F* tests and respective *p*-values were calculated using Kenward-Roger's approximation. The model showed only a significant main effect of distractor strength, $F(2,16.19)$=3.64, $p$<0.05. The main effect of accuracy [$F(1,13.45)$=2.40, $p$=0.14] and the interaction between accuracy and distractor strength [$F(2,415.42)$=0.14, $p$=0.87] were not significant predictors of RT. Planned contrasts (adjusted using a Bonferroni correction) showed that participants were significantly slower when a strongly-related distractor was present in the array compared to baseline trials in which no related distractor was present, $F(1, 16.70)$=7.64, $p$=0.003. The difference between weakly-related distractor trials and baseline trials, $F(1,16.76)$=0.60, $p$=1.00, and the difference between strongly-related and weakly-related distractors, $F(1,17.03)$=2.77, $p$=0.34, were not significant.
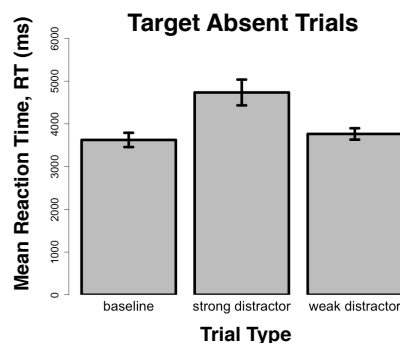


Figure 3: Mean RT per trial type in the Visual Search task. Error bars display standard errors of the mean.

## Discussion

The goal of this experiment was to examine if estimates of semantic relatedness as measured by a Match-to-Sample task converged with performance in a Visual Search task. Specifically, for each target item we selected two related items that varied in how strongly they were judged to be related to the target (one *strongly-related* and one *weakly-related* distractor) in a Match-to-Sample task, and tested the effect of each type of distractor on children's ability to search for that target. Our finding that strongly- but not weakly-related items influenced children's ability to indicate the absence of a target provides initial evidence that Visual Search task performance is influenced by semantic relation strength in children. As such, the Visual Search task is a promising alternative to the Match-to-Sample task, addressing the limitations of this task as outlined above.

### Using Visual Search to study the development of semantic knowledge

Semantic knowledge exerts a pervasive influence on cognitive processes. This knowledge about objects, facts,

and concepts deeply influences how people search for information in the environment (Moores et. al, 2003), retrieve information from memory (Bower et al., 1969), make predictions about objects (Coley et al., 2004), or make sense of events (McNamara & Kintsch, 1996). Despite the important role that semantic knowledge plays in organizing efficient behavior, we still have a limited understanding of how this knowledge is acquired and how its structure changes with experience. Currently, one obstacle to study the development of semantic knowledge and how it changes with experience is the lack of measures that can be used across the lifespan; as outlined in the Introduction, the most commonly used measure, the Match-to-Sample task, is not well-suited to do so. Visual search paradigms may be a viable alternative as they have been extensively used with adults to study many facets of knowledge (Huettig et al., 2005), and some recent work with toddlers shows similar evidence in younger populations (Chow et al., 2017).

This paradigm also shows promise in capturing individual variation among children. Figure 4 shows participants RT (subtracted from baseline trials RT) to indicate the target's absence from the visual array when the strongly-related and the weakly-related distractors were present. Each bar depicts the relative response time of a single participant, indicating how much that participant was affected by the presence of the related distractor. The range of variability suggests that this task may be a promising tool to study how individual differences in semantic knowledge contribute to individual differences in processes theorized to rely on semantic knowledge (e.g. Fisher, 2015).

Together, the present data suggest that a Visual Search paradigm both complements the Match-to-Sample paradigm and potentially addresses many of its limitations. Below we discuss some of the unresolved questions and important future directions of this work.
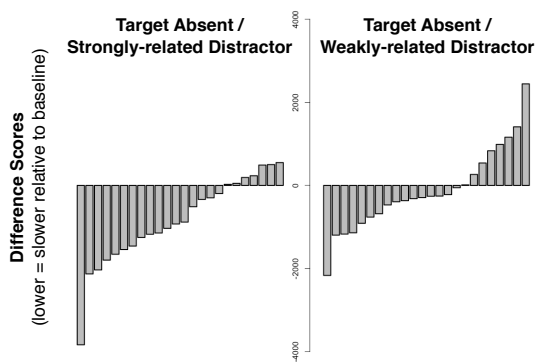


Figure 4: RT difference scores, calculated as: related-absent trials (i.e. baseline) minus related present trials.

## Unresolved questions and future steps

The present study revealed no evidence that the presence of a weakly-related distractor influenced search performance. One possibility is that our RT measure was insufficient to detect subtler effects of semantic relatedness. More fine-grained moment-to-moment measures taken while children are looking for the target may detect these effects. Indeed, prior research that found graded effects of knowledge associated with a target concept made use of higher resolution measures, such as eye-tracking or mouse-tracking (e.g. Mirman & Magnuson, 2009). Another possibility is that children's performance in the Match-to-Sample task is idiosyncratic, and the findings of our calibration study do not generalize across children. To address this possibility, we retested in the Match-to-Sample task all children who participated in the Visual Search task; the estimates were comparable across the two samples, lending some confidence to the estimates from the stimuli selection study.

As this was the first attempt at using the Visual Search task to measure semantic knowledge in young children, we were agnostic as to which relations to probe and thus imposed no constraint when selecting the target-distractor pairs. In the current set of items, some items are linked by multiple relations (e.g. *chair* and *table* are both furniture items and often co-occur in the environment, and thus share two types of relations), while other items share only one type of relation (e.g. *carrots* and *rabbit*). Previous research using a spatial arrangement task showed that young children seem to consider items that share multiple relations as being more strongly related than items that share only one relation (Unger et al., 2016), and thus it is possible that items that are related in more than one way more strongly influence performance in a Visual Search. Future work can more closely test this prediction by systematically selecting stimuli that vary in the types of relations depicted.

We also did not control for visual similarity between targets and distractors. It is well known that visual similarity influences visual search (e.g. Vales & Smith, 2015); when selecting the visual tokens, we selected items that were easily discriminable both within- and between-categories, but we did not empirically measure visual similarity. Although it is not trivial to obtain a pure measure of similarity (see Medin et al., 1993; Chow et al., 2017), some recent work has tried to address these issues (e.g. De Groot et al., 2016), and as such it will be important to try to more systematically measure visual similarity in future studies.

## Conclusions

The present study demonstrates the Visual Search paradigm as a feasible approach to investigate the development of semantic knowledge. In contrast with paradigms commonly used in prior research, this paradigm is age-appropriate across a wide developmental range, and greatly reduces the influence of deliberative processes on performance. Thus, the Visual Search task has the potential to shed new light on the development of semantic knowledge and its role in a variety of cognitive processes.

# References

Arias-Trejo, N., & Plunkett, K. (2009). Lexical–semantic priming effects during infancy. *Philosophical Transactions of the Royal Society of London B: Biological Sciences*, *364*(1536), 3633-3647.

Baayen, R. H., Davidson, D. J., & Bates, D. M. (2008). Mixed-effects modeling with crossed random effects for subjects and items. *Journal of Memory and Language*, *59*(4), 390-412.

Bates, D., Maechler, M., Bolker, B., & Walker, S. (2015). Fitting Linear Mixed-Effects Models Using lme4. *Journal of Statistical Software, 67*(1), 1-48.

Bower, G. H., Clark, M. C., Lesgold, A. M., & Winzenz, D. (1969). Hierarchical retrieval schemes in recall of categorized word lists. *Journal of Verbal Learning and Verbal Behavior*, *8*(3), 323-343.

Clark, E. V. (1973). What's in a word? On the child's acquisition of semantics in his first language. In T. E. Moore (Ed.), *Cognitive development and the acquisition of language* (pp. 65–110). New York, NY: Academic Press.

Chi, M. T., Feltovich, P. J., & Glaser, R. (1981). Categorization and representation of physics problems by experts and novices. *Cognitive science*, *5*(2), 121-152.

Chow, J., Davies, A. A., & Plunkett, K. (2017). Spoken-word recognition in 2-year-olds: The tug of war between phonological and semantic activation. *Journal of Memory and Language*, *93*, 104-134.

Chun, M. M., & Jiang, Y. (1998). Contextual cueing: Implicit learning and memory of visual context guides spatial attention. *Cognitive psychology*, *36*(1), 28-71.

Coley, J. D., Hayes, B., Lawson, C. A., & Maloney, M. (2004). Knowledge, expectations, and inductive reasoning within conceptual hierarchies. *Cognition, 90,* 217–253.

De Groot, F., Koelewijn, T., Huettig, F., & Olivers, C. N. (2016). A stimulus set of words and pictures matched for visual and semantic similarity. *Journal of Cognitive Psychology*, *28*(1), 1-15.

Fisher, A.V. (2015). Development of inductive reasoning. Child Development Perspectives, 9(3), 172-177.

Gerhardstein, P., & Rovee-Collier, C. (2002). The development of visual search in infants and very young children. *Journal of Experimental Child Psychology*, *81*(2), 194-215.

Gobbo, C., & Chi, M. (1986). How knowledge is structured and used by expert and novice children. *Cognitive Development*, *1*(3), 221-237.

Godwin, K. E., & Fisher, A. V. (2015). Inductive generalization with familiar categories: developmental changes in children's reliance on perceptual similarity and kind information. *Frontiers in psychology*, *6*.

Huettig, F., & Altmann, G. T. (2005). Word meaning and the control of eye fixation: Semantic competitor effects and the visual world paradigm. *Cognition*, *96*(1), B23-B32.

Huettig, F., Rommers, J., & Meyer, A. S. (2011). Using the visual world paradigm to study language processing: A review and critical evaluation. *Acta Psychologica*, *137*(2), 151-171.

Kaldy, Z., Kraper, C., Carter, A. S., & Blaser, E. (2011). Toddlers with autism spectrum disorder are more successful at visual search than typically developing toddlers. *Developmental Science*, *14*(5), 980-988.

McClelland, J. L., & Rogers, T. T. (2003). The parallel distributed processing approach to semantic cognition. *Nature Reviews Neuroscience, 4*, 310–322.

McNamara, D. S., & Kintsch, W. (1996). Learning from texts: Effects of prior knowledge and text coherence. *Discourse Processes*, *22*(3), 247-288.

Medin, D.L., Goldstone, R.L., & Gentner, D. (1993). Respects for similarity. *Psychological Review,* 100, 254-278.

Mirman, D., & Magnuson, J. S. (2009). Dynamics of activation of semantically similar concepts during spoken word recognition. *Memory & Cognition*, *37*(7), 1026-1039.

Moores, E., Laiti, L., & Chelazzi, L. (2003). Associative Knowledge Controls Deployment of Visual Selective Attention. *Nature Neuroscience*, *6*(2), 182-189.

Roediger, H. L., & McDermott, K. B. (1995). Creating false memories: Remembering words not presented in lists*. Journal of Experimental Psychology: Learning, Memory, and Cognition, 21*, 803–814.

Smiley, S. S., & Brown, A. L. (1979). Conceptual preference for thematic or taxonomic relations: A nonmonotonic age trend from preschool to old age. *Journal of Experimental Child Psychology, 28*, 249–257.

Unger, L., Fisher, A. V., Nugent, R., Ventura, S. L., & MacLellan, C. J. (2016). Developmental changes in semantic knowledge organization. *Journal of Experimental Child Psychology*, *146*, 202-222.

Vales, C., & Smith, L. B. (2015). Words, shape, visual search and visual working memory in 3-year-old children. *Developmental science*, *18*(1), 65-79.

Vales, C., & Smith, L. B. (2017). The words they know: Individual differences in how language affects visual processing. Talk presented at the *Biennial Meeting of the Society for Research in Child Development*. Austin, Texas.

Walsh, M., Richardson, K., & Faulkner, D. (1993). Perceptual, thematic, and taxonomic relations in children's mental representations: Responses to triads. *European Journal of Psychology of Education, 8*, 85–102.

Waxman, S. R., & Namy, L. L. (1997). Challenging the notion of a thematic preference in young children. *Developmental Psychology, 33*, 555–567.

Xu, F., & Tenenbaum, J. B. (2007). Word learning as Bayesian inference. *Psychological Review*, *114*(2), 245.