Running head: WORDS LOWER THRESHOLD FOR OBJECT IDENTIFICATION

When a word is worth more than a picture:

Words lower the threshold for object identification in 3-year-old children

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Abstract

A large literature shows strong developmental links between early language abilities and later cognitive abilities. We present evidence for one pathway by which language may influence cognition and development: by influencing how visual information is momentarily processed. Children were asked to identify a target in clutter, and either saw a visual preview of the target or heard the basic-level name of the target. We hypothesized that the name of the target should activate category-relevant information, and thus facilitate more rapid detection of the target amid distractors. Children who heard the name of the target before search were more likely to correctly identify the target at faster speeds of response, a result that supports the idea that words lower the threshold for target identification. This finding has significant implication for understanding the source of vocabulary-mediated individual differences in cognitive achievement and more generally for the relation between language and thought.

Keywords: language; vision; object recognition; visual perception; cognitive development

When a word is worth more than a picture: Words lower the threshold for object identification in 3-year-old children

Many traditional theories of cognitive development regard language as a transformative force on cognition, enabling children to think abstractly, to control their cognitive processes, and to reason about instances that cannot be directly perceived. As Vygotsky famously noted, "The child begins to perceive the world not only through his eyes but also through his speech. As a result, the immediacy of "natural" perception is supplanted by a complex mediated process." (Vygotsky, 1978). Here we show evidence consistent with the idea that language changes other cognitive abilities, and provide one mechanism by which words may do so in children as young as three: by changing in-the-moment processing of visual information.

A large literature shows that a child's language proficiency is related to their cognitive skills. Early individual differences in vocabulary size and semantic knowledge predict *later* intelligence (Marchman & Fernald, 2008), school readiness (Morgan, Farkas, Hillemeier, Hammer & Maczuga, 2015), and behavior regulation (Petersen et al., 2013). Although these relations have been established, the developmental pathways through which language influences other cognitive abilities are not known. In the laboratory, heard words have been shown to influence how long children sustain attention on an object (Baldwin & Markman, 1989), how children compare and categorize visual objects (Ferry, Hespos & Waxman, 2010; Yoshida & Smith, 2003), and how children reason about relations within and among objects (Dessalegn & Landau, 2013; Loewenstein & Gentner, 2005). While these results suggest that language influences foundational cognitive processes, they do not elucidate the specific mechanisms by which language learning affects so many aspects of cognition.

One pathway through which language and language learning could influence performance in different domains is by influencing how visual information is momentarily processed. This idea has been considered in the context of traditional debates on whether language can influence perception, or whether human cognition is based on nonmalleable

percepts (Gleitman & Papafragou, 2012). Although we will consider these classic questions in the Discussion section, our hypothesis about how language influences the online processing of visual information is based on findings from adults suggesting that words have direct effects on visual processes (Lupyan & Spivey, 2010; Ostarek & Huettig, 2017). Most human learning and performance has substantial visual components (Ahissar & Hochstein, 2004). Thus, if words can influence how children momentarily process visual information, this would constitute a plausible mechanism for how language could have pervasive effects into other cognitive abilities. We investigate this question by examining how children identify a target object in clutter, one domain in which words have been shown to affect visual processing in adults.

When presented with a cluttered array of objects and the goal of finding a particular target, the perceiver has to compare the incoming visual information from the array with a memory or representation of the target (Hout & Goldinger, 2015). Adult performance in these tasks depends on the information provided *before* the search array is presented (Vickery, King, & Jiang, 2005), with naming the target being positively related to target identification (Lupyan & Spivey, 2010). This is thought to reflect a process whereby words activate visual memories about the categories of objects to which they refer (Lupyan, 2008; Lupyan & Thompson-Shill, 2011; see also Jonides & Gleitman, 1972), including relevant low-level visual information that lowers the threshold to identify an object (Ostarek & Huettig, 2017). Here we ask if words have similar effects on 3-year-old children's identification of objects in clutter. On the one hand, these young children are at the beginning of the long developmental trajectory of word learning and visual object recognition (Smith, 2003) and differ from older children and adults in how they process visual objects (e.g., Mash, 2006). Thus, it is possible that words will not influence how such young children visually identify objects. The alternative possibility, that words do influence how children identify objects in clutter, would constitute a potential causal explanation for the power of language on cognitive development.

In the current experiment, 3-year-old children searched for a target that was an instance of a category (e.g., ice cream) among distractors that were instances of other visually-similar categories (e.g., balloons, lamps). In the *Label* condition, children heard the spoken name of the target object prior to search; in the *Visual Preview* condition, children saw a visual preview of the target object prior to search. The experimental question was this: When identifying a target in an array of visually-similar distractors, does hearing the basic-level name of the target object lower the threshold to identify the target *relative to* seeing a visual preview of the actual target? Both hearing the name and seeing a preview of the target have been shown to facilitate target identification in adults (Lupyan & Spivey, 2010; Vickery, King, & Jiang, 2005), and the combination of a label and a visual preview has been shown to increase the speed with which 3-yer-old-children identified a target object relative to a visual preview (Vales & Smith, 2015). Here, we test the more consequential prediction that the name of the target alone facilitates target identification more than does a visual preview of the to-be-found object. Our reasoning is this: If the name of the target activates category-relevant information for object identification, then hearing the name of the target object should activate a better visual representation of the target than seeing a visual preview of the target. This is because the visual preview of the target will activate both category-general and item-specific information (e.g., Hollingworth, Williams, & Henderson, 2001); this item-specific information, by not discriminating target and distractors, should make target identification more difficult.

To test the hypothesis that labels lower the threshold for target identification, we used a child-friendly version of a response deadline task. This approach, by forcing participants to respond rapidly, measures the minimal time needed to make a correct decision given the presented information (e.g. Pachela, Fisher & Karsch, 1968). If the threshold for identifying the target is lowered by hearing the name of the target, then the minimal time needed to identify the target should be less in the Label condition than in the Visual Preview condition. The key prediction thus concerns rapid responding: When responding *rapidly*, children should be more

likely to respond *correctly* in the Label condition than in the Visual Preview condition. While fixed brief deadlines and the possibility of many errors are typical of deadline tasks, these task properties are unlikely to yield useful data from 3-year-old children. Accordingly, instead of imposing deadlines, we encouraged children to respond rapidly but let children self-pace their responses. Similar to the analytic approach of deadline tasks, we then systematically related the time taken to respond to the likelihood of correctly identifying the target across the two conditions. Although this approach does not manipulate response deadlines, it nevertheless allows us to examine the relation between time taken to respond and accuracy, a relation that is informative of how children identify a target in clutter when shown its visual preview versus hear its name (see Fitts, 1966; Ratcliff, 1985) and whether the minimal time needed to make a correct decision is lowered by hearing the name of the target (Pachela, Fisher & Karsch, 1968).

Method

Participants

Fifty-two children between 32 and 41 months of age (23 girls, *M*=37 months, *SD*=2.4) were randomly assigned to the Label condition or the Visual Preview condition, and to one of two targets (ice cream or cup), with equal number of children assigned to each condition and target. Calculating power for the intended generalized linear mixed effects analyses relating response time to accuracy is not trivial (Johnson, Barry, Fergurson, & Müller, 2015). Additionally, to the best of our knowledge, there are no prior studies with children participants relating response time to the likelihood of making a correct response to provide an expected effect size. Accordingly, we approximated our sample size by calculating the target sample size for a traditional linear regression model assuming a small effect size (0.15), alpha-level of 0.05, and power level of 0.80; this yielded a total sample size of 55. To satisfy the between-subjects assignment to condition and target, we recruited 52 children. Children were recruited from a predominantly working- and middle-class population in Bloomington, Indiana in the Midwestern United States and tested in

the laboratory. English was the main language spoken by all families. Thirteen additional children were recruited but not included in the analyses due to parental interference (N=2), refusal to participate or failure to complete all test trials (N=10), and English not being their main language (N=1). Parental consent was obtained for all children in compliance with the IRB of Indiana University, and all children received a toy for participating. Parents were asked to complete the CDI-III inventory (Fenson et al., 2007), a normed productive vocabulary checklist with 100 words; six families did not complete or return the inventory. Children in the two conditions did not differ in the mean number of words in their productive vocabularies *(M_{Visual}=71, M_{Label}=70, t(44)=0.23, p=0.81, Cohen's d=0.07).*

Stimuli and Design

Two target categories were used, ice cream and cup. For each target, the distractors were items of other categories. For the target ice cream, the distractors were tokens of lamps, balloons, and glasses; for the target cup, the distractors were tokens of hats, pots, and balls. In order to test the hypothesis that hearing the name of the target object, by not including item-specific information, should activate a better representation of the target than seeing its visual preview, the distractor categories were selected to be visually hard to discriminate from the target, while sharing minimal phonological overlap with the name of the target (see Vales & Smith, 2015, Experiment 3). All categories of items used are highly familiar to children of this age (see Vales & Smith, 2015, Experiment 3), and with one exception ("pot") their names are known by at least 50% of children before 30 months (Fenson et al., 2007). To prevent color information from guiding search, the pictures of targets and distractors were recolored in red scale; pictures were rendered in a 100x90 pixel area on a white background. The audio files used to present the name of the target in the Label Condition were recorded using an artificial speech creator at a sample rate of 16KHz.

Children completed 36 test trials in which they searched for the same target category. The target was always present, and across test trials, it was displayed equally often on the left and

right sides of the screen. To maintain the difficulty of the task and increase the variability of the response time measure, the number of distractor items varied across trials, and multiple tokens of the target and distractor categories were used. Within each block of 9 trials, there were three occurrences of each distractor set size (3, 9, or 12 distractors), with the order randomized for each child. On each trial, there were the same number of tokens of each distractor category (e.g. for set size 9, there were three tokens of each of the three distractor categories). For each target and distractor category, 18 unique tokens were used (see Figure 1 in the Supplemental Materials). Within each block of 18 trials, there was one occurrence of each target/distractors token pairing.

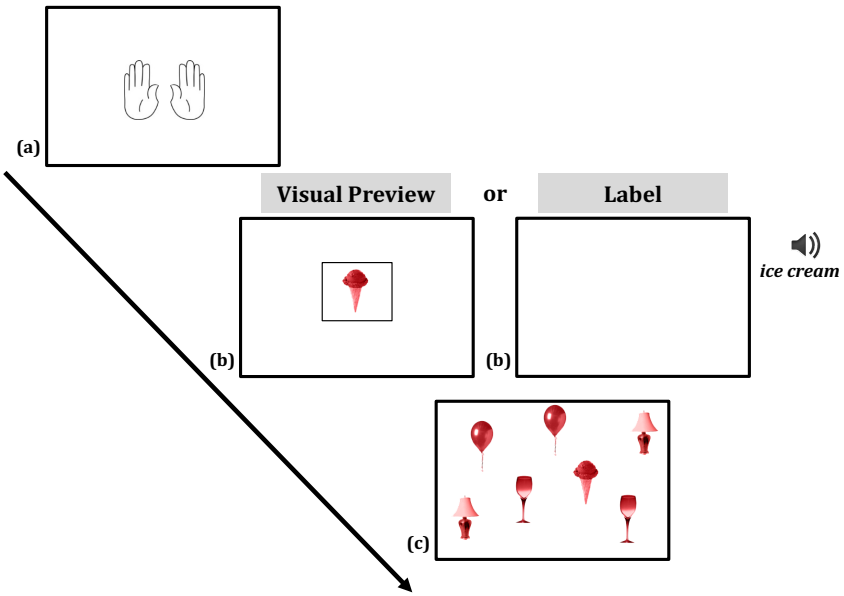

Figure 1. Structure of a trial in the experiment; participants in the Visual Preview condition were presented with the visual preview in silence, and participants in the Label condition were presented with the spoken name of the target while a blank screen was on. After 1 second, participants were presented with the search array and asked to identify the target by touching it.

Procedure

Children sat in front of a 17" monitor equipped with a touchscreen layover (MagicTouch, Keytec, Garland, TX). E-Prime (PST, Pittsburgh, PA) was used to present the stimuli and to record

participants' responses. Figure 1 depicts the structure of a single trial. On each trial, a "fixation" slide was presented to prompt the child to rest their hands on the table below the screen; this ensured children's manual responses had similar starting points across trials. The experimenter pressed a keyboard key to present the cue screen once the child was looking at the screen; participants in the Label condition were cued with the spoken name of the target object (e.g., "ice cream") while a blank screen was on, and participants in the Visual Preview condition were cued with a silent visual preview of the exact target object for that trial (see Figure 1 in the Supplemental Materials). The search array was displayed after 1s and the child was asked to identify the target picture and touch it; the trial ended once a manual response was detected. No time limit was imposed, but children were reminded to find the target picture as fast as possible. In giving task instructions, the experimenter did not label any of the objects, instead saying "Watch the picture!" or "Listen up!" before the cue slide, and "Can you find it?" during the response screen. No feedback was given; children were given neutral encouragement regardless of performance (e.g., "Thanks for your help finding the pictures") and given stickers to maintain their interest in the task; the stickers were put inside a container and kept out of the child's view. Before the experimental trials, children completed a familiarization phase to be acquainted with preparing for the upcoming trial by keeping their hands on the table, listening to the audio cue (in the Label condition) or watching the visual cue (in the Visual Preview condition) before the search array was displayed, and touching the target as soon as they identified it on the search screen; during this familiarization phase, children were given feedback as needed. Pictures of smiley faces, crayons, pencils, bicycles, and motorcycles were used as targets and distractors during this familiarization phase.

Results

Because we are interested in examining the relation between response time (RT) and accuracy across the two experimental conditions, we first examine whether the two conditions differ on

each individual measure. We start with an analysis of children's RT in the two conditions regardless of whether the RTs were associated with correct or incorrect responses, followed by an analysis of children's accuracy in the two condition irrespective of time taken to respond. These analyses show that, when considering RT and accuracy separately, the two conditions do not differ in how long children take to make a response, or how likely children are to correctly identify the target object. We then test our hypothesis by examining the relation between response time and accuracy; this analysis shows that time taken to respond differentially affects how accurate participants are across the two conditions.

Response time measures

In the adult literature, response time is used to index processing time for correct responses – the longer it takes the perceiver to respond, the more effortful it is to process the presented information for the task at hand (Pachella, 1974). Within the present approach of measuring accuracy as a function of RT, we need RT to reflect the processing time required to yield a correct response; however, by not imposing response deadlines, there could be trials in which children took a long time to respond that did not reflect effortful processing, but being off-task. However, because of their skewed distributions, it is not trivial to identify outliers in RT data (Ratcliff, 1993; Whelan, 2008), and this may be particularly problematic when a small number of observations is collected from each participant (Ratcliff, 1993), as is often the case with children participants. Given these considerations, we only excluded trials in which children took longer than 10s to make a response; this threshold was decided upon visual inspection of the RT distribution (see Figures 2 and 3 in the Supplemental Materials) and resulted in the exclusion of 5.6% of all data. We also excluded trials in which children took less that 500ms to respond, resulting in the additional exclusion of 0.96% of all data (see Table 1 in the Supplemental Materials for number of trials included per condition). These exclusion criteria are similar to those used in past work with young children (e.g., Frank et al., 2016), and as described below, all results remain unchanged when we include these trials.

Table 1 shows descriptive statistics for each condition, and Figure 2 depicts the RT distributions for all trials (correct and incorrect) across the two experimental conditions after exclusions. The two conditions did not differ in how long participants took to make a response, $t(50)=0.30$, $p=0.77$, Cohen's d=0.08. To further examine potential differences between the two conditions, their distributions were compared using a bootstrapping version of the Kolmogorov-Smirnov test with 1000 samples; this test showed that the RT distributions of the two conditions were not significantly different (D=0.028, $p=0.89$). We also examined whether the number of distractor items across trials differentially influenced how long children took to make a response (regardless of accuracy) across the two conditions (see Table 1). An ANOVA with distractor set size (3, 9, 12) as a within-subject factor and condition (Label Condition, Visual Preview Condition) as a between-subjects factor revealed a main effect of distractor set size on RT, $F(2,100)=69.3$, $p < 0.001$, $\eta^2=0.22$, but no interaction between distractor set size and condition, $F(2,100)<1$, $p=0.88$, $\eta^2<0.001$. Both analyses produced equivalent results when all trials were included (see additional analyses A in the Supplemental Materials). Together, these analyses suggest that there are no overall RT differences between the two conditions, and that the number of items in the array did not differentially affect how long children took to make a response across the two conditions.

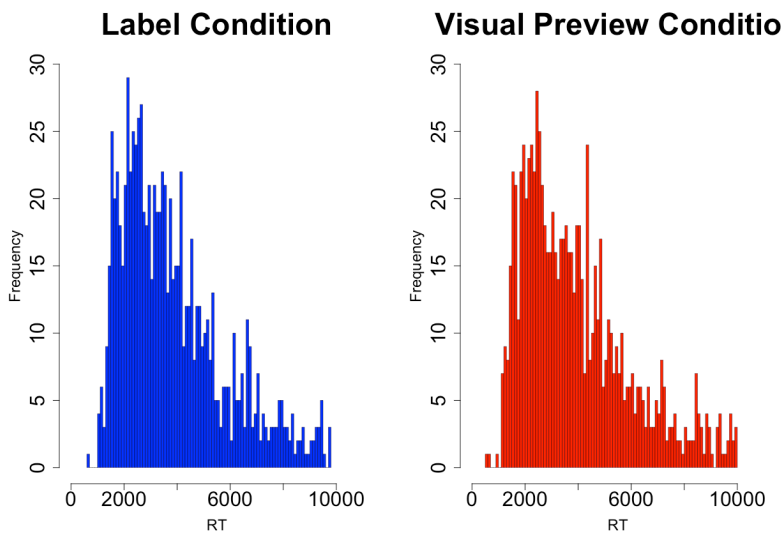

Figure 2. Response time distributions (ms) for the two experimental conditions for both correct and incorrect responses.

Accuracy measures

The mean proportion of correct responses was calculated for each subject by dividing the number of trials in which the target was correctly identified by the total number of trials in the task. As can be seen in Table 1, overall children were accurate at identifying the target, which indicates an understanding and commitment to the task. The two conditions did not differ in the overall likelihood of identifying the target, $t(50)=-1.02$, $p=0.31$, Cohen's d=-0.29. To assess whether the number of distractors influenced the two conditions differently, an ANOVA with set size (3, 9, 12) as a within-subject factor and condition (Label Condition, Visual Preview Condition) as a between-subjects factor revealed a main effect of distractor set size on accuracy, $F(2,100)=4.90$, $p=0.009$, $\eta^2=0.02$, but no interaction between set size and condition, $F(2,100)=1.15$, $p=0.32$, $\eta^2=0.005$ (see Table 1). Both analyses produced equivalent results when we included only trials in which children took more than 500ms or less than 10s to respond (see additional analyses B in the Supplemental Materials). Together, these analyses show that children in both conditions identified the target in clutter at similar rates across the two conditions, and that the number of

items in the visual array affected children's ability to identify the target to a similar extent in both conditions.

			Label Condition		Visual Preview Condition	
			Mean	*SE*	*Mean*	*SE*
All trials	Overall response time (ms)		4358	259	4430	272
	Response time per distractor set size (ms)	3 distractors	3495	205	3586	236
		9 distractors	4466	312	4529	292
		12 distractors	5113	325	5175	331
	Overall proportion of correct responses		0.90	0.02	0.87	0.03
	Proportion of correct responses per distractor set size	3 distractors	0.92	0.03	0.91	0.02
		9 distractors	0.90	0.02	0.85	0.03
		12 distractors	0.90	0.03	0.84	0.04
After RT outlier exclusion	Overall response time (ms)		3884	169	3954	161
	Response time per distractor set size (ms)	3 distractors	3286	165	3306	148
		9 distractors	3982	202	4043	207
		12 distractors	4430	204	4551	189
	Overall proportion of correct responses		0.91	0.02	0.89	0.03
	Proportion of correct responses per distractor set size	3 distractors	0.92	0.02	0.92	0.02
		9 distractors	0.91	0.02	0.88	0.03
		12 distractors	0.90	0.02	0.87	0.04

Table 1. Response time and accuracy measures in the two experimental conditions. The top section displays the summary for data from all trials, and the bottom section displays the summary data for data without trials in which children took less than 500ms or more than 10secs to make a response.

Relation between Response Time and Accuracy

The key prediction concerns how accuracy relates to response time in the two conditions. If words influence visual processing by changing the threshold to accurately identify the target, then any facilitation in finding the target after hearing its name relative to seeing its visual preview should be more pronounced at faster speeds of response. Figure 3 depicts the relations between time taken to make a response and likelihood of correctly identifying the target; for the purposes of displaying the data, the RT variable was aggregated into three bins with approximately the same number of trials each (see Table 1 in the Supplemental Materials). Children in the Visual

Preview condition were more likely to correctly identify the target when they took longer to make a response, whereas children in the Label condition were more accurate at faster speeds of response; in addition, children in the Label condition also seem more likely to be correct at the fastest response times than children in the Visual Preview condition. To analyze these patterns, we used a generalized linear model approach (Liang & Zeger, 1986; Zeger & Liang, 1986) to model the relation between RT and accuracy across the two experimental conditions; this allowed us to model the RT measure as a continuous predictor of a repeated categorical response (i.e., for each subject, correct or incorrect response at the trial level) and examine whether their relation was different for the two conditions. We implemented the model in the R environment (R Core Team) using the geeglm function from the geepack package (Højsgaard, Halekoh & Yan, 2006). To model the binary outcome (i.e., correct or incorrect response), we used a logit link function and a binomial variance function. Because we did not have a-priori hypotheses regarding how responses were correlated across trials, we used an independent correlation structure (also see Zeger & Liang, 1986 for how generalized linear models are robust to misspecifications of the correlation structure). The variables RT (as a continuous variable) and Condition (Label condition, Visual Preview condition) were sequentially entered, followed by an interaction term; the RT variable was centered to decrease the differences in the scales of the model parameters. The anova function was used to calculate sequential Wald tests and respective *p*-values for each added variable. Both RT (b= -0.0002, STE= 0.00005, Wald $\chi^2(1)=1.68$, $p=0.19$) and Condition (b=-0.4, STE=0.4, Wald $\chi^2(1)=0.61$, $p=0.44$) did not have an effect on accuracy. However, the interaction between response time and condition had an effect on accuracy, b= 0.0003, STE= 0.00009 , Wald $\chi^2(1)=12.13$, $p= 0.0005$, showing that the relation between the time taken to respond and the likelihood of correctly finding the target is not the same across the two experimental conditions. Adding distractor set size to the model did not change the overall results (see additional analyses C in the Supplemental Materials). Finally, the interaction between

RT and condition still has a significant effect on accuracy when the model included all trials (i.e., when it included trials taking less that 500ms and more that 10s; see additional analyses D in the Supplemental Materials).

Taken together, the results are consistent with our hypothesis that words lower the threshold to correctly identify an object. These results show that while the two conditions do not differ overall in how long children take to make a response or how likely children are to find the target, the two conditions do differ in the function that relates accuracy to response times. Participants in the Label condition were very accurate at finding the target at very fast response times, while children in the Visual Preview condition were more accurate when they took longer to make a response.

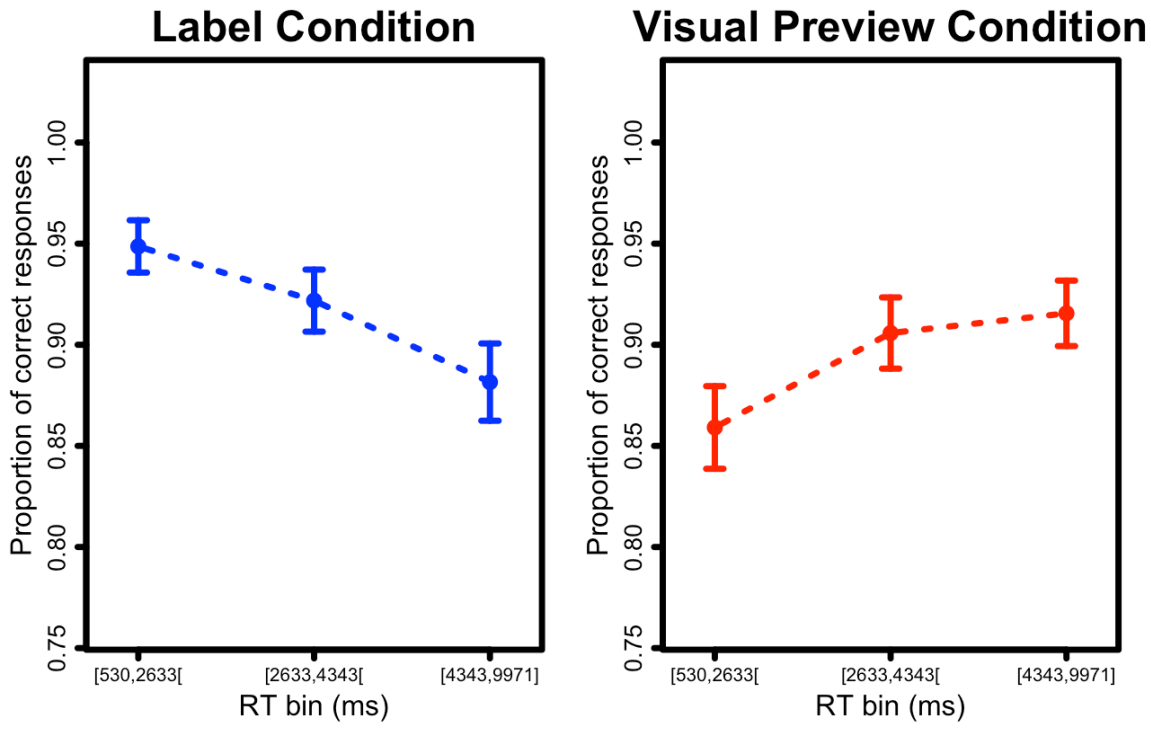

Figure 3. Mean proportion of correct responses per Response Time bins in the two conditions. Error bars display standard errors of the mean. The RT bins were calculated for a single distribution that included the two conditions. The RT data were only binned to graphically display the relation between the two variables, the RT per trial was entered into the model as a continuous variable (see Table 1 in the Supplemental Materials for more details).

Discussion

The results show that words influence the speed with which children can identify a target in a cluttered array, with children being more likely to correctly identify the target at faster speeds of response when a word, relative to a visual preview, was presented; this concurs with the hypothesis that words lower the threshold to identify a visual object. The clear implication is that words create an internal target representation that is in some way different than that created by seeing the actual target during the visual preview. Lastly, the results support the more specific idea that, relative to visual information, words may be better activators of category-defining properties that distinguish the target from items of other categories. These findings have important consequences for understanding the role of language in learning and development, and for understanding individual differences in cognitive development.

While prior work shows that words change children's performance in many laboratory tasks (Baldwin & Markman, 1989; Loewenstein & Gentner, 2005; Yoshida & Smith, 2003), these do not locate the effects at the level of object identification. Motivated by prior findings from the adult literature, we hypothesized that by activating category-relevant information, words would lower the threshold to identify an object in clutter. Contemporary research shows the reach of top-down information in influencing early visual areas (Ahissar & Hochstein, 2004; Bar et al., 2006; Rahman & Sommer, 2008), including cascading effects into areas that support discrimination along category-relevant dimensions (De Baene, Ons, Wagemans, & Vogels, 2008; Folstein, Palmeri, and Gauthier, 2012). The demonstration that these effects hold even in very young children who are still building vocabularies and category knowledge (Smith, 2003) is a significant new contribution because these effects of words on momentary visual object detection have the potential to fundamental change what children learn and how they perform across many different cognitive tasks.

Words that change the speed with which objects are detected in clutter will have powerful effects, influencing how well children can link the words they hear to specific referents and

elements in the visual world, and supporting online sentence comprehension and learning in informal learning settings and in school (Ferreira, Apel, & Henderson, 2008; Marchman & Fernald, 2008). Indeed, this one effect may be the ultimate explanation of why words influence how children remember and generalize newly learned object names (Samuelson, 2002; Yoshida & Smith, 2005), the rate at which they learn new words (Perry, Samuelson, Malloy & Schiffer, 2010), and the specific words they learn next (Colunga & Simms, 2017) – effects which likely underlie the predictive relations between early vocabulary size and later cognitive achievements. If a heard known word momentarily changes visual processing with effects on what is detected in a cluttered world and later remembered, then these individual moments of experience may accumulate to yield a visual system with stronger top-down effects – and thus not just quicker visual processing in the moment, but fundamentally different visual inputs to other cognitive systems (Oakes, 2017). While these effects may be small in any one moment, the aggregate of many small benefits of words constitutes a plausible mechanism for how early language proficiency is such a strong predictor of later cognitive achievements.

The current results are also relevant for the larger theoretical discussion on language and thought, and whether language shapes human cognition or is impermeable to linguistic influences. Traditionally, this question has been investigated by comparing adult speakers of different languages to examine whether they perform differently in non-verbal tasks that require distinctions more strongly highlighted by one of the languages (Gleitman & Papafragou, 2012). If they do, then differences in the task must result from experience with different languages, and thus language can change cognition. However, disentangling and reconciling the contributions of linguistic and non-linguistic processes is not trivial (Li & Gleitman, 2002; Pederson et al., 1998). While we did not show that language changes performance in a purely non-linguistic task – the gold standard within some theoretical frameworks for showing an effect of language on perception – the results did show that the category name speeds the detection of a visual target relative to seeing the specific target to be found. If words systematically influence the

momentary processing of information even in just this one way, in the long term they will alter what children learn and know about the world. Because different languages differ in the categories they lexicalize, the accumulation of experiences with words and scenes could yield differences in object recognition (Kuwabara & Smith, 2016), as well as in more general knowledge.

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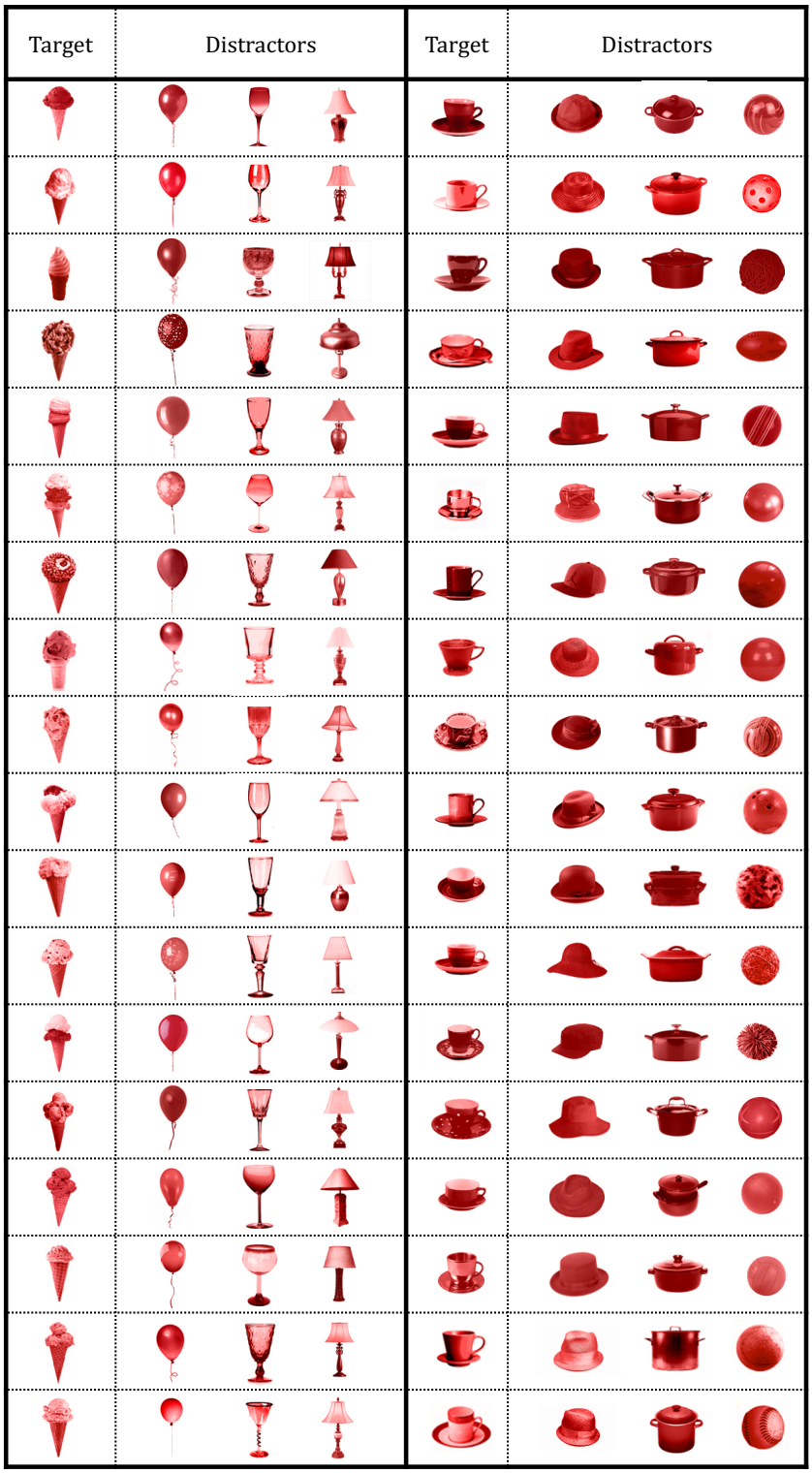
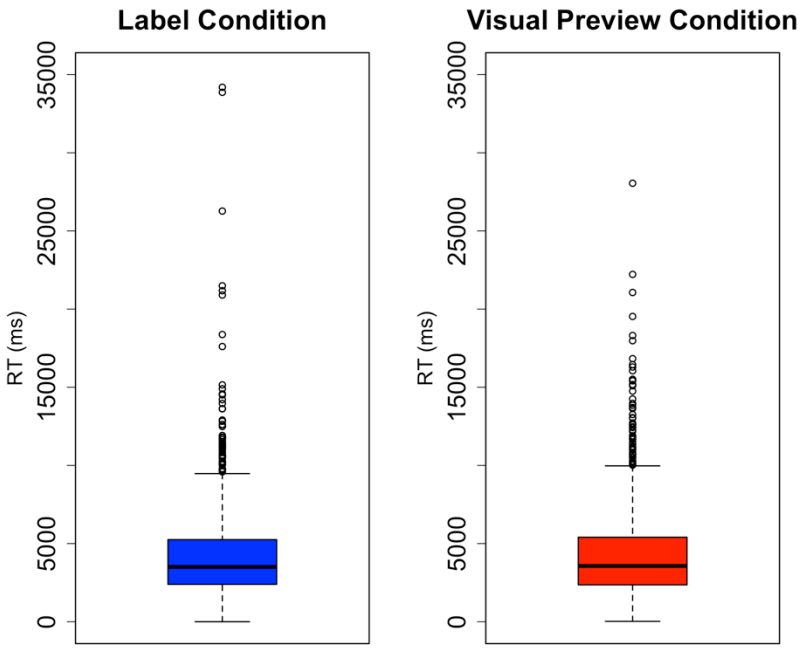
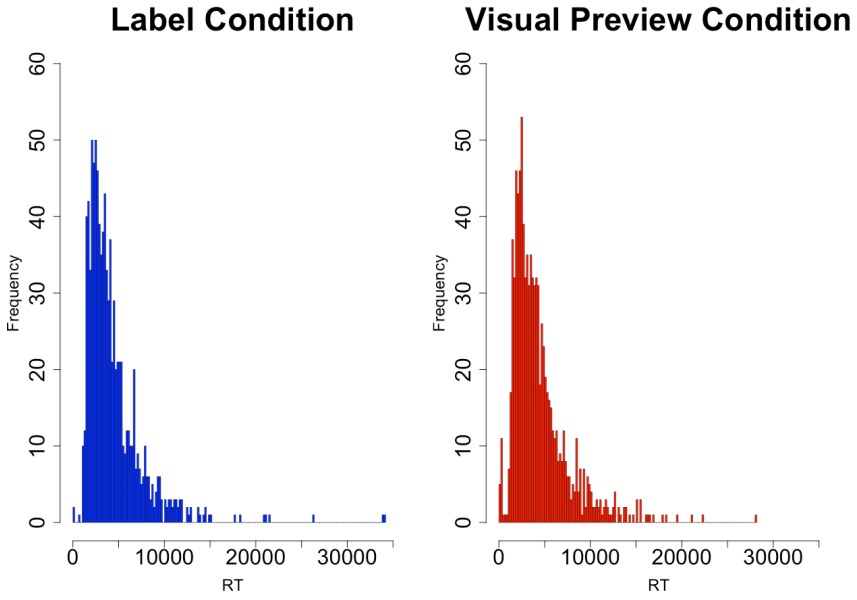
SUPPLEMENTAL MATERIAL



Supplemental Material – Figure 1. Full stimulus set. Targets (*ice cream* or *cup*) were placed amidst the corresponding distractors (*balloon*, *glass*, and *lamp;* or *hat*, *pan*, and *ball*, respectively).



Supplemental Material – Figure 2. Box-and-whisker plots of all RT data (i.e., including responses taking <500 ms or >10 secs).



Supplemental Material – Figure 3. Histograms of all RT data (i.e., including responses taking <500 ms or >10 secs).

		1st bin	2nd bin	3rd bin
Label Condition	RT (ms)	635-2646	2647-4260	4261-9798
	Number of trials	292	307	287
Visual Preview Condition	RT (ms)	530 - 2616	2617 - 4371	4372-9971
	Number of trials	291	276	296
Both conditions combined	RT (ms)	530-2633	2634-4343	4344-9971
	Number of trials	583	583	583

Supplemental Material – Table 1. Reaction Time (ms) and number of trials in each bin per condition, and when the two conditions are combined (after excluding trials in which participants took less than 500 ms or more than 10 secs to respond). Because the two conditions did not differ in their RT distributions, and because their tertile cut-offs were very similar, we used the tertile cut-offs for both conditions combined when graphically displaying the data (see Figure 3 in the manuscript).

Additional analyses A: RT distributions analyses when all trials are included (i.e., including responses taking <500 ms or >10 secs):

As reported in the manuscript, we found no overall differences in RT between the two conditions, nor evidence that the number of items in the array differentially affected how long children took to make a response across the two conditions; those analyses were conducted after excluding trials in which children responded too quickly or took too long to make a response. However, we find the same pattern of results when all trials are included. Specifically, the two conditions did not differ in how long participants took to make a response, $t(50)=0.19$, $p=0.85$, Cohen's d=0.05; the RT distributions of the two conditions were not significantly different, D=0.027, $p=0.89$ (bootstrapped Kolmogorov-Smirnov test); and while there was a main effect of distractor set size on RT, $F(2,100)=72.6$, $p < 0.001$, $\eta^2=0.17$, there was no interaction between distractor set size and condition, $F(2,100)<1$, $p=0.99$, $\eta^2<0.001$. These results suggest that the RT exclusion criteria do not influence these results.

Additional analyses B: Accuracy analyses when excluding responses taking <500 ms or >10 secs:

As reported in the manuscript, we found that children in both conditions identified the target in clutter at similar rates across the two conditions, and the number of items in the visual array affected children's ability to identify the target to a similar extent in both conditions. As our main analysis of accuracy as a function of RT excluded trials in which children were too fast (<500 ms) or too slow (>10 secs) to respond, we additionally conducted the same analyses of accuracy, but including only trials in which children took more than 500m or less than 10 secs to respond. These analyses show no evidence that the two conditions differ in overall accuracy, $t(50)=-0.62$, $p=0.52$, Cohen's d=-0.18, nor that the number of items in the search array differentially affects how accurate children are at identifying the target across conditions, $F(2,100)=0.69$, $p=0.50$, $\eta^2=0.004$, which suggests that the RT exclusion criteria do not influence these results.

Additional analyses C: RT/Accuracy relation, Model with fixed effect of distractor set size:

As reported in the manuscript, we found an interaction between time taken to respond and condition on the likelihood of correctly identifying the target. Because we manipulated distractor set size across trials to increase the variability of the RT measure, we additionally conducted the same analysis of accuracy as a function of RT but adding number of distractors (as a continuous variable). This analysis found that the interaction between RT and condition remained the only significant effect on accuracy, b=0.0003, STE= 0.0002, Wald $\chi^2(1)=12.12$, $p=0.00005$).

Additional analyses D: RT/Accuracy relation, Model with all trials (i.e., including responses taking <500 ms or >10 secs):

As reported in the manuscript, we found an interaction between time taken to respond and condition on the likelihood of correctly identifying the target. As this analysis excluded trials in which children were too fast (<500 ms) or too slow (>10 secs) to respond, we additionally conducted the same analysis of accuracy as a function of RT, but including all trials. We found that the interaction between condition and RT was still a significant predictor of accuracy in the model, (b=0.0002, STE=0.00006, Wald $\chi^2(1)=8.61$, $p=0.0033$); we note that while Condition was still not a significant predictor of accuracy in this model (b=-0.5, STE=0.3, Wald $\chi^2(1)=1.14$, $p=0.29$), RT was (b=2.38, STE=0.23, Wald $\chi^2(1)=11.33$, $p= 0.00076$).