Title

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Abstract

Recent research suggests that children's ability to learn words via fast mapping is strongly related to the attentional demands of the task. Here we explore whether lowering the attentional demands during the initial fast mapping task facilitates word learning. Three-year-old children completed fast mapping and test trials using a touch screen computer. For half of the children, the non-targets (competitors) repeated across trials and for other children there was no repetition. All children received the same word learning test trials. Only children who had received repeating competitors (lower attentional demands) during the initial fast mapping task demonstrated word learning. Thus, these data suggest that children's ability to learn novel names is strongly influenced by the competition and attentional demands of the initial fast mapping context.

Keywords: fast mapping; word learning; competition; attentional demands.

Does Fast Mapping Enable Word Learning?

Learning to comprehend the vast number of words that children are bombarded with daily is a daunting task. Arguably, it is equally daunting for researchers to explain the mechanisms responsible for children's developing ability to understand what a speaker is referring to when uttering a new word, but also children's ability to remember the link between the word and referent for later encounters.

Without direct instruction, children effectively determine the referent for a novel word on their own—particularly when the referent is presented in the context of known objects. Typically referred to as fast mapping (Carey, 1978), children appear to determine the referent via process-of-elimination (Halberda, 2003). That is, children use their prior knowledge (i.e., known vocabulary) to rule out the objects they have already linked to a name. Instead, they select a novel object as the likely referent of a novel name. Biases to novelty appear to be key in fast mapping. Recent research further indicates that even in the context of other nameless, novel objects, children will select the most novel object as a referent for a novel name (Horst, Samuelson, Kucker, & McMurray, 2011; Mather & Plunkett, 2012).

However, fast mapping is not word learning per se, but rather an initial step in the word learning process (Carey, 1978; Horst & Samuelson, 2008). Fast mapping appears to be relatively easy for children, yet retention of the name-object mappings is more difficult. For example, Horst and Samuelson (2008) presented 24-month-old children with referent selection (i.e., fast mapping) trials with one novel object and two known objects. Only 5 minutes later, they tested children's retention for the same novel name-object associations by presenting the targets among other novel targets that had been encountered during the initial referent selection trials and foils that had been seen during a preferential looking task. Children had little difficulty selecting the correct referents on the initial referent selection trials. However, children performed at chance levels on the retention trials, suggesting that the initial name-object mappings did not lead to robust representations in long-term memory. Other studies have found similar difficulties in long-term retention of name-object mappings despite demonstrations of minimal difficulty disambiguating novel from known objects (e.g., Bion, Borovsky & Fernald, 2013; Gureen, Horne & Erjavec, 2012).

Note, other studies do suggest minimal exposure to a novel word and object may lead to long-term retention of the association, but these have typically involved only naming a single novel object (e.g., Woodward et al., 1994). It remains unclear, therefore, whether children's selection of the target on the delayed test trials are really in response to the specific phonetic content of the new word or because that word was the only new word introduced during training, rendering it unique among the available alternatives (Dollaghan, 1985; Schafer & Plunkett, 1998).

Task Demands

Taken together, these studies suggest that children are adept at forming the initial associations between novel referents and their names, however, children's ability to retain these mappings may suffer when task demands are high. For example, in a recent study exploring the effect of the number of known competitors present during the initial fast mapping task on subsequent word learning, 2-year-old children were only able to retain novel name-object associations when task demands were relatively low (Horst, Scott & Pollard, 2010). Specifically, children were only able to retain words when they had seen few known competitors across fast mapping trials (eight) but not when they had seen more competitors across trials (12 or 15)—although the number of targets was the same for all groups.

Clearly then, the non-target competitors play an important role in word learning via fast mapping. Horst and Samuelson (2008) found that children could only retain the novel name-object associations when ostensive naming was

provided after each fast mapping trial. That is, when the experimenter picked up a novel object, pointed to it and restated its name. Importantly, the experimenter physically moved the target away from the known competitors. For another group of children, naming was also provided after each trial, however, targets were not moved away from the competitors. These children did not learn the name-object associations. The authors argue that ostensive naming helps children focus on the target while simultaneously drawing their attention away from the competitors.

A follow-up study explicitly tested this explanation of ostensive naming by illuminating targets from below (a light flashed inside the tray the objects were on) and by covering competitors with semi-opaque boxes (Axelsson, Churchley & Horst, 2012). Children who received this form of ostensive naming learned the name-object associations. The authors argue that ostensive naming helped children better encode the name-object association as their attention to the target object was sustained. Children who only received ostensive naming in the form of pointing (without moving the target away from the competitors) did not demonstrate significant word learning.

In both of these examples, the initial fast mapping task was made easier by decreasing the attentional demands. Specifically, the experimenter helped guide the child's attention away from the competitors, which facilitated processing of the targets.

Similarly, increasing attentional demands can also have a detrimental effect on subsequent word learning. Wilkinson, and colleagues (2003) presented one group of children with fast mapping trials with one novel object and three known competitors. Another group received fast mapping trials where each successive trial included not only a novel object and two known competitors, but also the novel object from the previous trial. Children who faced such increased attentional demands were less successful on subsequent fast mapping trials. Because children typically prefer novelty (Horst et al., 2011; Mather & Plunkett, 2012), the presence of another novel object likely decreased attention to the target.

Contextual Repetition

Similar effects of the reduction of attentional demands during word learning tasks have been demonstrated in other contexts (for a review, see Horst, 2013). In an investigation of word learning via shared storybook reading, Horst, Parsons and Bryan (2011) found that 3-year-old children who were read the same storybooks repeatedly (three times) successfully retained novel words from the books when tested one week later. In contrast, children who were read three different stories performed at chance levels when tested on the same novel words one week later. Importantly, children in both groups were exposed to the same number of novel words the same number of times. The critical difference was that the first group encountered the words in the same context repeatedly whereas the second group encountered them in different contexts. The authors

concluded that children who encountered words in repeated contexts were at an advantage because they had less information to process, facilitating long-term retention of the name-object associations. The question that remains unanswered, then, is whether the same mechanism is at play in other contexts.

The Current Study

The aim of the current study is to examine the effect of contextual repetition during fast mapping on subsequent word learning. To examine the effects of the learning context, children either saw novel objects with the same or different known competitors across trials. Specifically, children either encountered the novel object in the same context (with the same competitors) across all three trials with that given target or encountered the novel object in different contexts (with different competitors) across trials. Thus, the attentional demands of the task were either relatively low (repeated contexts) or relatively high (different contexts). Therefore, the degree of attentional demand was expected to differ across the four groups during the fast mapping trials. As in the storybook studies (e.g., Horst et al., 2011), those presented with repeated contexts (competitors) during novel target referent selection trials were predicted to perform better at test. As attentional demands are presumably high during referent selection of novel objects, the repetition of competitors may aid in long-term learning of name-object mappings.

Method

Participants

Forty-eight typically developing, monolingual, English-speaking children aged 36 months (*M* age 36 months, 13 days, *SD* = 73.79 days; range 33 months, 0 days – 41 months, 30 days; 24 girls) participated. Children were from predominantly white, middle class homes recruited from southern England. Data from 1 additional child were excluded because she consistently touched the screen before waiting to hear the instructions. Parents were reimbursed for travel expenses and children received a small gift.

Stimuli

Digital photographs of known (familiar) and novel objects served as the target stimuli. Specifically, six known objects (ball, cup, train, cow, frog, elephant) and three novel objects (the end of a foam arrow/*zorch*, a y-shaped rubber dog toy/*gaz* and a clacker/*sprock*) served as target stimuli on the referent selection trials. The known objects were chosen because they are highly familiar to 3-year-old children. The novel objects were chosen because they are unfamiliar to most 3-year-old children and they do not know names for these objects. Additional photographs of three aliens, a bed and a dresser were used during the experiment. A female, native British English speaker narrated the procedure for the child (henceforth the narrator).

Procedure and Design

During the experiment, children were seated on their parents' laps at a table in front of a Dell computer with a touchscreen monitor. The keyboard and mouse were out of the children's reach. Stimuli were presented using ePrime 2.0. Children were asked if they would like to play a computer game. During the experiment, the experimenter stood behind the child to ensure the child remained on task, to answer questions and to minimize parental interference.

Introduction and Warm-up Trials The first screen depicted a red alien who the narrator introduced as Modo. The recorded script was carefully written so that no pronouns were used: thus each child could decide if Modo was male or female. The next screen depicted a bed, a dresser and small versions of each of the known and novel objects that would later be used on the referent selection trials. The narrator explained that Modo was very messy and asked if the child would "help tidy up Modo's room."

Three warm-up trials immediately followed. These trials served to introduce the child to the task and to help the child feel comfortable touching the computer screen. On each trial the child was presented with three additional known objects and asked to select an object by the narrator, e.g., "Can you find the spoon? Touch the spoon." If the child had not yet touched the screen after 1000ms, the recording repeated and continued to loop with 1000ms in between requests for up to 30 seconds, or until the child touched the screen. After the child touched a picture, a blank, white screen appeared to give the experimenter a moment to praise the child. The same objects were presented on each warm-up trial, but object positions (left, middle, right) were counterbalanced across trials so that each object appeared once in each position. Thus, the child was asked for a different object in a different position on each warm-up trial and could practice touching an object at each possible position.

Referent Selection Trials Referent selection trials immediately followed the warm-up trials and followed the same procedure except that children did not receive feedback after these trials. On each referent selection trial the child was presented with two known objects (e.g., elephant, cup) and one novel object (e.g., clacker) and asked to choose either a known or novel object, e.g., "Can you find the *sprock*? Touch the *sprock*." Children were presented with 18 referent selection trials including 9 known

name and 9 novel name referent selection trials, of which there were 3 trials for each novel name (e.g., 3 *sprock* trials). Which objects children saw on these trials varied across conditions depending on whether or not the same competitors were repeated across trials (see Table 1).

For half of the children the same competitors were repeated across all trials for a given novel name. For example, each time they were asked for the *sprock* (clacker), it was displayed with the elephant and the cup. For the other children, different competitors were displayed on each trial for a given novel name. For example, the first *sprock* trial may have included the elephant and cup, the second *sprock* trial the train and frog and the third *sprock* trial the cow and ball. Object animacy was also counterbalanced across trials.

Likewise, for half of the children, the same competitors were repeated across all trials with the same known name. For example, each time they were asked for the elephant, it was displayed with the cup and *sprock* (clacker). For the other children, different competitors were displayed on each known name referent selection trial. For example, the first elephant trial may have included the cup and *sprock*, the second elephant trial the ball and *zorch*, and the elephant was also a competitor along with the *gaz* on a train trial. Importantly, all children saw the same six known objects and three novel objects across referent selection trials an equal number of times. However, for this to evenly occur some targets (e.g., elephant) were also competitors in the non-repeat conditions.

This resulted in a 2x2 design with four conditions: competitors repeat across all trials (i.e., both trial types), competitors repeat across novel trials (but not known trials), competitors repeat across known trials (but not novel trials) and competitors do not repeat on any trials. One can also consider the four conditions of the current study on a continuum of attentional demands from low (competitors repeat across all trials) to intermediate (competitors repeat across novel trials or competitors repeat across known trials) to high (competitors never repeat).

Children were asked for each of the novel targets once during trials 1-6, once during trials 7-12 and once during trials 13-18. Each novel target appeared once in each position (left, middle, right) when it was a target and once in each position when it was a competitor during the known name trials. The same objects were never presented on two consecutive trials and no more than two trials of either type (i.e., known or novel targets) were presented sequentially.

Table 1: Example targets and competitors (comp.) for the Repeat Across All Trials and the No Repeat Conditions.

Trial	Target	Comp. 1	Comp. 2	Trial	Target	Comp. 1	Comp. 2
	Repeat Across All Trials				No Repeat Across Trials		
1	Sprock	Elephant	Cup	1	Sprock	Elephant	Cup
7	Sprock	Elephant	Cup	8	Sprock	Train	Frog
14	Sprock	Elephant	Cup	11	Sprock	Cow	Ball
4	Elephant	Cup	Sprock	5	Elephant	Frog	Sprock
10	Elephant	Cup	Sprock	13	Elephant	Ball	Zorch
17	Elephant	Cup	Sprock	18	Train	Elephant	Gaz

Word Learning Trials After the final referent selection trial, the screen showed the bed, dresser and the small stimuli pictures from before but displayed in neat rows and the narrator told the child the room was now tidy. The next screen showed Modo with another alien who was blue. The narrator explained that Modo's friend ZeeBee had come over to play and asked if the child could help Modo share toys with ZeeBee. Then, the word learning test trials were presented again following the same procedure. Importantly, the word learning trials were the same for all conditions. On each trial all three novel objects were displayed and the child was asked to choose an object. Children were asked to choose each target once (for a total of 3 trials). Each novel object appeared once in each position (left, middle, right). At the end the narrator told the child "It's fun to share toys!"

Results

Referent Selection Trials

As can be seen clearly in Figure 1, children in all four conditions performed very well during the initial referent selection task. On the known name referent selection trials, children chose the target object significantly more than would be expected by chance (.33) in the repeat across all trials condition ($t(11) = 19.34$, $p < .001$, $d = 5.53$), in the repeat across novel trials condition ($t(11) = 14.45$, $p < .001$, $d = 4.12$), in the repeat across known trials condition ($t(11) = 44.78$, $p < .001$, $d = 12.78$) and the no repeat condition ($t(11) = 29.40$, $p < .001$, $d = 8.40$), all ps two-tailed. Children's proportions of target choices on the known name referent selection trials were submitted to an ANOVA with competitors repeat across novel trials (yes, no) and competitors repeat across known trials (yes, no) as between-subjects factors. The ANOVA yielded no significant effects, indicating that contextual repetition during referent selection did not influence children's ability to select known objects.

Similarly, on the novel name referent selection trials, children chose the target object significantly more than would be expected by chance (.33) in the repeat across all trials condition ($t(11) = 6.30$, $p < .001$, $d = 1.82$), in the repeat across novel trials condition ($t(11) = 6.96$, $p < .001$, $d = 2.02$), in the repeat across known trials condition ($t(11) = 18.35$, $p < .001$, $d = 5.23$) and the no repeat condition ($t(11) = 11.08$, $p < .001$, $d = 3.18$), all ps two-tailed. Children's proportions of target choices on the novel name referent selection trials were submitted to an ANOVA with competitors repeat across novel trials (yes, no) and competitors repeat across known trials (yes, no) as between-subjects factors. The ANOVA yielded no significant effects. Thus, contextual repetition during referent selection did not influence children's ability to select novel objects either.

Word Learning Trials

In contrast, contextual repetition during referent selection did influence children's *learning* of previously fast-mapped novel names. As can be seen in Figure 2, children in the repeat across all trials and repeat across novel trials conditions identified referents of novel names at rates significantly greater than expected by chance (.33), both $t(11) = 3.87$, $p < .01$, $d = 1.12$. However, in contrast, children in the repeat across known trials and the no repeat conditions performed at chance levels, $t(11) = 1.50$, *ns*, and $t(11) = 1.20$, *ns*, respectively. Thus, repeating the same competitors across multiple novel name referent selection trials did influence children's ability to learn novel words.

To best understand the individual contributions of repeating the competitors on both novel and known name referent selection trials, children's proportion of target choices on the word learning trials was submitted to an ANOVA with competitors repeat across novel trials (yes, no) and competitors repeat across known trials (yes, no) as between-subjects factors.
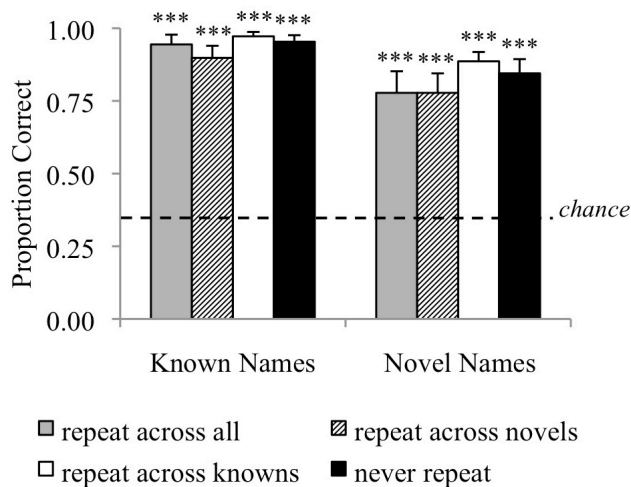

Figure 1. Children's proportion correct during the referent selection trials. Dotted line indicates chance (.33), error bars indicate 1 standard error from the mean. *** $p < .001$.
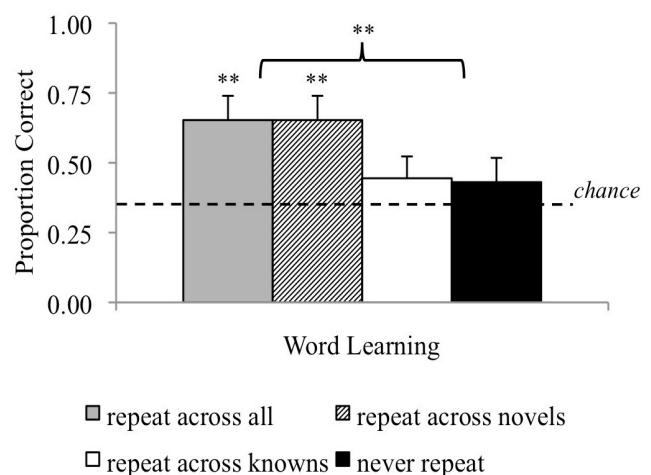

Figure 2. Children's proportion correct during the word learning test trials. Dotted line indicates chance (.33), error bars indicate 1 standard error from the mean. ** $p < .01$.

The ANOVA yielded a main effect of repeat across novel trials, $F(1,44) = 6.99$ $p = .01$, $\eta_p^2 = .14$. Children in the conditions where competitors repeated across novel trials learned more words ($M = .65$, $SD = .29$) than children in the conditions in which competitors did not repeat across novel name referent selection trials ($M = .44$, $SD = .27$). No other significant effects were found. These findings clearly demonstrate that repetition of competitors during novel name referent selection influences later word learning.

Reaction Times

Finally, we wanted to assess how the attentional demands of the task influenced children's performance throughout the experiment. To this end, we examined children's reaction times (RTs) on all correct trials over the course of the experiment. RTs were submitted to an ANOVA with competitors repeat across novel trials (yes, no) and competitors repeat across known trials (yes, no) as between-subjects factors and encounter (first, second, third, fourth) as a repeated-measure (the fourth encounters were the word learning trials). The ANOVA yielded a significant main effect of encounter, $F(2.57, 94.96) = 10.39$, $p = <.001$, $\eta_p^2 = .22$. Overall, children became faster over the four encounters. There was also a significant encounter by competitors repeat across novel trials interaction, $F(2.57, 94.96) = 3.63$, $p = .02$, $\eta_p^2 = .09$ (see Figure 3).
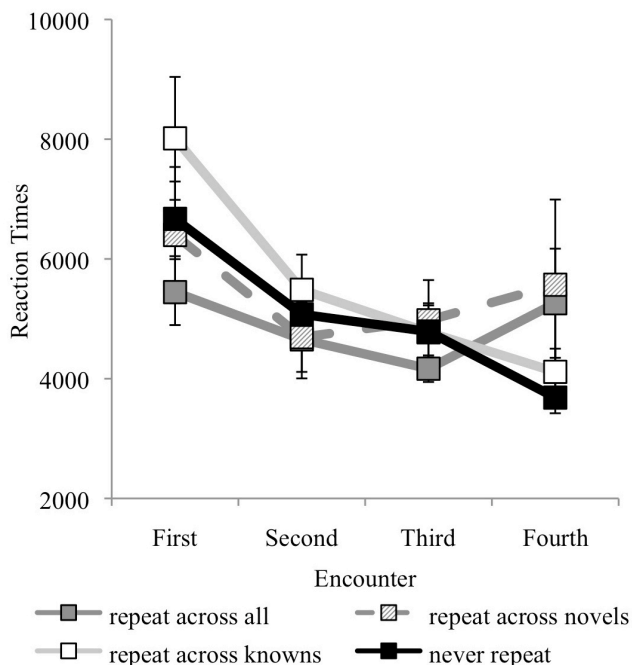

Figure 3. Children's reaction times across encounters to the novel targets including during the initial fast mapping trials (First, Second, Third encounters) and the word learning test (Fourth encounter).

Further analyses revealed a significant linear trend for this interaction, $F(1,37) = 6.88$, $p = .01$, $\eta_p^2 = .16$. Specifically, in the conditions where the competitors did not repeat across novel trials RTs decreased from the first to the fourth encounter. In contrast, in the conditions where the competitors did repeat across novel trials RTs became faster during referent selection (first three encounters) but slowed down again on the word learning test (forth encounter).

RTs to the fourth encounter (i.e., word learning test trial) were then compared. In the conditions where the competitors did repeat across novel trials, children were marginally slower on the word learning test trials ($M = 5408.09$ms, $SD = 3870.36$ms) than children in the other conditions ($M = 3909.67$ms, $SD = 1100.29$ms), $t(25.91) = 1.79$, $p = .084$, two-tailed, $d = 0.60$. This difference in RTs is interesting because it suggests that children in the different groups were processing the names and objects differently. Children in the conditions with high task demands (competitors did not repeat across novel name referent selection trials) may have been simply guessing on these trials—hence the quick RTs. In contrast, children in the conditions with low task demands (competitors repeated across novel name trials) may have been committed to the task and searching for the correct referent—hence the slower RTs. Overall, these data demonstrate that lowering the attentional demands through repeating contexts (competitors) facilitated word learning and influenced processing as measured by reaction times.

Discussion

Word learning is typically a gradual process as children experience the statistical regularity of the co-occurance of a name and object across repeated encounters (Smith & Yu, 2008). Repeated encounters also facilitate retention for novel name-object associations (e.g., Gurteen et al., 2012). In everyday life, children may be exposed to some names and objects multiple times in the same context (e.g., a rubber duck in the bathtub). When a new word and its referent are repeatedly encountered in the same context, the non-targets may become increasingly redundant and predictable, freeing up attentional resources for processing the target referent (for a review and discussion of how this relates to research using storybooks, see Horst, 2013).

The current study investigated the effect of contextual repetition in referent selection trials on word learning. The results demonstrate that children presented with contextual repetition (i.e., the same competitors across multiple novel name referent selection trials) were significantly better at learning the target words than children who did not receive contextual repetition. Repeating competitors across trials appears to facilitate the initial encoding of the novel targets, enabling robust learning of the name-object associations. Children may have also associated the targets with the context of the non-targets (e.g., *sprocks* occur with elephants and cups), as they likely do with real-life objects (e.g., rubber ducks occur with bathtubs). One could argue that this gave targets on the contextual repetition trials a "figure-ground advantage," however, this is an unlikely

explanation as the objects were all presented on a plain white background as in previous studies (e.g., Schafer, 2005), rather than as part of a real scene.

We also found a difference in reaction times between conditions in which the competitors repeated across novel trials and conditions in which the competitors did not repeat. Although all children responded faster across successive encounters with the novel target, the children who saw the same competitors across novel name trials slowed down on the word learning trials when the novel target was presented with the other novel objects. This group may have been meaningfully considering among the possible test alternatives while those who saw different competitors may have been responding randomly at test, resulting in speedier responses. Although all children received the same number of exposures to the target items, only those for whom the context repeated across exposures demonstrated significant word learning.

Other studies, however, indicate that variability across learning encounters may facilitate learning. (e.g., Thiessen, 2011). An important consideration, however, is what is varying and what is remaining constant (i.e., repeating). Previous studies have typically found an advantage for variability at the target-level across encounters. Here, we demonstrate an advantage for reducing variability at the non-target-level (i.e., the competitors). Future research is needed to investigate when and how variability and reduction of attentional demands work together to facilitate robust word learning over both short- and long-term timescales. Clearly, however, for word learning via fast mapping, reducing the attentional demands of the initial referent selection task facilitates subsequent word learning.

Acknowledgments

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