Prediction and Hypothesis Testing in Children's Novel Word Learning

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Abstract

Children learn new words through a variety of methods, consciously and unconsciously making connections between novel words and new objects to expand their vocabulary. One such method may be making predictions about the meaning of a novel word presented to them and subsequently testing their prediction. Existing literature provides only suggestive evidence that prediction and hypothesis testing should support word learning. In this study, we investigated the importance of prediction and hypothesis testing in word learning. We did this by showing children novel and familiar objects and encouraging them to either make predictions and test hypotheses about new words or not. Results displayed no difference in word learning based on prediction and hypothesis testing.

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Introduction

Growing your vocabulary should be a difficult task considering the number of possible associations between objects and their labels, yet without any immediate additional context children can figure out what new words mean. When learning a new word, children have to sift through a continuous stream of information, identify specific words they do not know, and understand what that new word is referring to within the context of the information presented to them. They must further map that new word onto something it refers to in the real world and draw an association with it that they can recall for future use. The situation is complex because each time a new label is provided, there are an infinite number of hypotheses children can make about the associations words can have (Quine, 1960). For example, a new word "chair" could refer to the legs of a chair, the backrest, the seat, or even an action of sitting itself. Yet, most children are able to correctly map the new label "chair" to its correct referent. They also acquire new words at a rapid pace, showing an almost automatic ability to discard other hypotheses in favor of the correct association more frequently than not (Bergelson & Swingley, 2013; Carey & Bartlett, 1978; Wojick, 2013). To understand how children sift through the many possible hypotheses to determine what "chair" could be referring to, it would be useful to understand how children make hypotheses and test their predictions in general contexts. Following this, I discuss research on the prediction and hypothesis testing in language processing. I then discuss evidence of the role of each process in the context of word learning.

Prediction and Hypothesis Testing in Children's General Learning

Prediction and hypothesis testing can be best understood as the process of making an observation, developing a targeted reaction (making a prediction), and responding to the event through an appropriate action (testing a hypothesis). An easy way to think about this concept is through the process of catching a ball. You observe your friend throwing the ball, make a prediction about its flight, and position yourself appropriately to catch it. This multi-step process happens rapidly, and while you may not always catch the ball, the active process of testing out your prediction by positioning yourself in the right place to catch it may start to happen early on in life.

The basic nature of making predictions and understanding the relation between cause and effect has been observed in children as young as three years old (Bonawitz et al. 2010). In this study, researchers showed children a sequence of events. A block was moved by a confederate to contact a base on a flat table that subsequently lit up when touched. This contact would also cause a toy connected to the base to spin but in fact, the trigger for the base was secretly activated by the confederate. In the observation phase, a confederate would touch the block to the base four times, activating the toy with every contact. However, on the fifth trial, the confederate touched the block to the base but did not activate the toy. The researcher would then note whether the child had looked at the toy in expectation that the toy would light up as it had in the preceding four trials. They found that almost all of the children looked at the base on the fifth trial, suggesting a predictive understanding that the block would light up the base. This suggests that children are capable of making predictions about events.

Children are not only capable of making predictions but are also able to communicate their hypotheses to others (Walker et al., 2017). In this study, researchers placed three colored chips in a toy's assigned bin. The chips generated effects when placed in the bin. Blue chips activated the light and the fan of the toy, the red chips only the light, and the green only the fan. When a bag of the chips was tipped into the bin, the fan and the light activated. Participants were asked to explain which combinations of chips could have activated both the light and the fan. Overwhelmingly, 5-year-olds chose the simple explanation that the blue chip resulted in this activation. This suggests that children are capable of making predictions about the nature of a cause-effect relationship and relaying that hypothesis to other individuals as well, showing an active use of prediction in domain-general contexts.

Studies on hypothesis testing on children's learning in domain-general contexts have shown that children disqualify hypotheses that contradict evidence that they have been provided. (Tuncer & Sodian, 2018). Here, researchers aimed to investigate whether children would correct a confederate if the confederate presented a hypothesis that ran against the causal association the children had been taught. Children between the ages of 3 and 6 were taught a novel hypothesis, "blue objects turn the light on" when presented with a box that lit up after objects were placed on it. Researchers would then present the child with a false hypothesis, "heavy objects turn the light on" and note whether the children corrected them or not. They found that once children had made a causal association between two objects, two-thirds of them would explore the evidence that would disqualify the false hypothesis the researcher would generate. Here, children are actively testing multiple hypotheses and relaying their arguments to the researchers, providing suggestive evidence that the children are undertaking hypothesis testing in disqualifying some hypotheses and accepting others.

Prediction and Hypothesis testing in Language Processing

In addition to research on prediction and hypothesis testing in general learning domains, there has also been research on how children make predictions and (possibly) test their hypothesis during sentence processing. A recent study conducted by Reuter et al. (2019) investigated whether 3-5-year-old predict the referent of a novel word based on linguistic context. The researchers used eye tracking to measure participants' gaze location relative to the target object. The researchers presented children with sentences that either included clear cues about upcoming referents (that would support predictions) or did not. The researchers also varied whether the label offered to children matched their prediction or not. For example, in the constrained sentence condition the researcher would say "Yummy! Let's eat soup. I'll stir it with a spoon/cheem." For an unconstrained sentence, where children were not able to make a prediction, the research would say "Neat! Look over there. Take a look at the spoon/cheem." The researchers hypothesized that the participants in the constrained condition would predict the word "spoon" due to its association with "soup" and when offered a "cheem" instead, would correct their prediction by looking to the novel object. The unconstrained sentences served as a baseline test to establish children's gaze for the novel and familiar referents tested in the study. The results of the experiment showed that the children that made looking gestures towards the expected sentence endings, suggesting that children can make predictions during sentence processing.

One of the ways we can see this expression of hypothesis testing in language processing is through pointing gestures as a method to verify a chosen hypothesis and dismiss alternative ones. Children display a broad ability to actively learn new words and engage with new information through pointing gestures. Infants as young as 12-month-olds point at objects expecting adults to offer information that allows them to understand the nature of the object (Rohlfing, Grimminger & Lüke, 2017). In fact, as children get older, they continue to use pointing as a method of acquiring new meanings and supporting learning.

Cameron & Xu (2010) addressed this idea by measuring the impact hand gestures had on the memory of novel words in preschoolers. Participants were told a simple, unique story of a lost dog that visited 10 locations on the trip home. Each location was tracked on a map with the locations randomly sorted on the map and each location referenced with an appropriate picture. Participants were asked to retell the story immediately after the researcher had finished conveying the story in the same manner as the researcher had in the same order of locations the dog travelled. In one condition, participants were encouraged to point at the locations the dog had travelled while retelling the story, while in another condition, participants were not allowed to point. The results of the study showed that children in the pointing condition recalled significantly more of the locations and action events than the children in the no pointing condition. This suggests that pointing at a preschool age not only helps children engage in hypothesis testing but also allow them to better make associations between newly learnt information (the stories of the animals) and real-world referents (the physical places on the map).

Prediction and Hypothesis Testing in Word Learning

Much of the literature in novel word learning explores the almost instantaneous ability children have to discriminate between a novel and a familiar object, rapidly associating the new label with the new object it refers to (Waxman & Booth, 2000). One explanation is that children use mutual exclusivity, a default learning heuristic to narrow the hypotheses children have about the referent of a new label (Spiegel & Halberda, 2011). Mutual Exclusivity leads children to assume that a new label does not belong to a known object with a known label (Jaswal & Markman, 2003). This allows them to discard a known word when discriminating between a known and an unknown word. For example, if offered a novel object and a spoon and asked to “point at the cheem”, children would associate the novel word “cheem” with the novel object, discarding the known word.

Suggestive evidence from studies investigating children's use of mutual exclusivity, provide additional support for children's use of prediction and hypothesis testing (see also Trueswell et al. 2013). Horst and Samuelson (2008) explored the efficacy of exclusion learning, finding suggestive evidence that making a prediction is helpful in word learning. In this study, researchers investigated the difference in the retention of novel labels by varying the nature of label presentation across different experiments in their study. In Experiment 1A, 24-month-old infants were presented with two familiar objects and one unfamiliar object they did not have a label for. The infants were asked to "Get the duck!" for the familiar object or "Get the blicket!" for the unfamiliar object. Through this procedure, children encoded the novel label "blicket" for the unfamiliar object, allowing children to make an initial prediction about the meaning of "blicket" and its physical referent. In this first experiment, children were able to select the correct object immediately, but did not retain the meaning after a delay. In Experiment 2, researchers offered participants the novel label of the unfamiliar referent *before* presentation of the object by naming it five times. After presentation of the object, the participant was asked to choose the unfamiliar object they believed the novel label referred to. In contrast to the first study, children were able to recall the labels after a delay. In conditions where the novel label was offered five times before the presentation of the novel object, participants were able to remember and reproduce the words after a delay. In conditions where the novel label was not offered before the presentation of the object, participants did not retain the novel words after a delay.

Similarly, Zosh et al. (2013), offers suggestive evidence that hypothesis testing can be useful in novel word acquisition. In their experiment, the researchers presented children with objects on a computer screen and asked the children to identify the referent of a novel label. In one condition, children were told, “This is a dax” in reference to its unfamiliar referent object. In another condition, participants were asked to, “Point at the dax.” Asking them to choose between an unfamiliar object (the dax) and a familiar object shown on the screen. Researchers found that under conditions where participants were told what the novel label refers to, they did not remember words as well as when they were asked to point to what they thought was the novel referent, i.e., to point at the dax. The higher word retention during conditions where participants were encouraged to point to the object suggests that participants benefited from testing their hypothesis about the meaning of the word.

Together these studies suggest that prediction and hypothesis testing may support memory of novel words. In Horst & Samuelson (2008), offering a word before the presentation of an object leads to more robust word learning. Children in this study may use the novel word to predict that a novel object will appear (though they do not know the specific features of the referent, they will be prepared for the appearance of an unnamed thing). The importance of hypothesis testing in word learning is suggested through the work of Zosh et al. (2013), where more robust word learning is seen when children are asked to point at a named referent versus not. Children in this study may have been encouraged to test their hypothesis about the referent of a newly learned label. It may be that the act of pointing in this case allowed children to test this hypotheses. Across the two studies there is suggestive evidence that prediction and hypothesis testing support word learning. However, conditions that explore a learning benefit from both prediction and hypothesis testing have not been explored in a single study. This study will thereby fill an important gap that currently exists in the literature considering the importance of prediction-based learning in word learning contexts.

The present study tests whether prediction and hypothesis testing support word learning. In particular, I tested whether 3-year-old children were more likely to identify the referent of a new word immediately after being provided with label information and whether they were more likely to remember the referent of a new word after a delay if they were asked to make a prediction (about the arrival for a novel object) and to test a hypothesis (about the referent of a new word). To test this, children were in one of two conditions: one condition where prediction and hypothesis testing occurred, and one where neither prediction nor hypothesis testing occurred. In the prediction and hypothesis condition, children were provided with a novel label before the presentation of the corresponding novel object (so they would predict a novel label was going to appear) and then asked to point at the object they believed the novel label referred to (to test their hypothesis about what the referent of the new word). In the condition without prediction and hypothesis testing, novel labels were not provided before novel objects were presented and children were not asked to point at the referent to test out what they thought the new word meant. I hypothesized that participants who were asked to make a prediction and test their hypothesis would score higher on word learning after a delay. It is possible they would also show a benefit immediately, but prior research provides mixed evidence to support this prediction.

Methods

Participants

Participants were 18 three-year-olds (n = 18, 9 males, 9 females, M_{age} = 42 months, range 36–47 months). Children were recruited through the Child Studies Registry at Peabody College. All participants were monolingual English speakers with no developmental delays. Five participants were excluded from analysis; 3 were excluded as they did not complete the study and a further 2 were excluded due to purposeful incorrect responses. Parents were asked to complete a demographic survey, the results of which showed that a majority of the participants identified as White (88%) , 6% of participants identified as Asian and the remaining 6% identified as American Indian. Just under half, of parents reported a household yearly income of $150,000 (43%) or more with a further 52% of parents reporting an income of $75,000 - $150,000 and one parent reporting an income less than $75,000.

Materials

Altogether, children were shown 12 familiar objects. Familiar objects were selected from royalty free images online that corresponded to familiar words that preschoolers were likely to know identified from the NOUN database (Horst & Hout, 2016). In addition, children saw 12 unknown objects that were selected from the NOUN database (Horst & Hout, 2016) based on their uniqueness and familiarity scale. Objects that were the least familiar to preschoolers in the database were chosen to ensure that the unfamiliar objects would not appear similar to the chosen familiar objects. A set of unknown words were chosen from the noun database, and one was assigned to each unknown object.

Objects were arranged into pairs of pictures that were presented to children in a binder. The first 3 pages of the binder included familiar-familiar pairs to serve as our 3 warm-up trials (balloon-orange, cake-cookie, cheese-truck). The following 24 pages included an unfamiliar-familiar pair on each page and served as our learning trials. After this there were 4 pages with 3 unfamiliar objects on each page that were used for memory trials. Finally, we included 1 page of a color post-test that included 9 main colors the preschoolers would be asked to report during learning trials. Each page was further separated by a neutral pink page as a distraction between trials.

Design and Procedure

The study used a between-subjects design. The study was conducted in-person, children sat diagonal to the researcher and was shown the binder on a table. Parents sat behind the child and were asked not to interact with the child or the study instructions during the course of the study. Children were randomly assigned to one of two conditions the baseline condition or the prediction and hypothesis condition. In the baseline condition, children were asked to sit on their hands (so they would not be tempted to point at objects). In the prediction and hypothesis testing condition, children were offered labels before being shown objects and were asked to point at the named object after being offered a label. In the baseline condition, children were offered labels once objects were shown and were asked if they could see the named object (rather than being asked to point at it). In the immediate test, children were asked to identify the color of the named object instead of asking them to point at it so that children were only pointing at objects in the prediction and hypothesis testing condition. During a delayed test, children were asked to point at the referent in both conditions.

The study started with three familiarization trials so that children could get used to the procedure. The familiarization trials followed the structure of the condition children were in. They were shown pairs of familiar objects and asked to point at the target familiar object (in the prediction and hypothesis condition) and then asked to report the color of the target object to determine whether they could correctly identify the object. The children were presented with two options to report the color of the object, the main color of the target object and the main color of the other object of the pair, “Is the cake white or is the cake brown?”

After the warm-up trials, the learning trials began.

In the prediction and hypothesis testing condition, children heard a novel label before being shown the test objects, as in: “Do you want to see a toma? One is a toma! Yeah! One of the things is a toma!” Following this, the object pair was revealed. After being presented with the object they were asked to point at the named referent “Can you *point* at the toma?” Following the pointing gesture, children were asked about the color of the target object. “Is the toma black or Is the toma white?” as our test of immediate learning. The experimenter would acknowledge this answer with a neutral response such as “Alright”, “Okay”, or “Thanks.” This procedure was repeated for each of the 24 novel-familiar pairs. In half of the trials, the children were asked about the familiar object (using the same language frames as above) in the novel-familiar pair and for the other half they were asked about the unfamiliar object in the other pair.

The baseline condition was identical except the children heard novel labels while the novel object was visible to them (using the sentence frames above), and they were not asked to point. Instead, the researcher replaced the word point with the word see in the instructions (e.g., “Can you *see* at the toma?”). Otherwise, the procedure was identical.

After children had been introduced to all of the novel-familiar pairs, the memory trials began. During the memory trials children were shown three objects – the target unfamiliar object, an unfamiliar object that they were asked to label but was not a target object, and an unfamiliar object that appeared alongside a familiar object but was not labelled. The position of the target object was counterbalanced across trials. In both conditions, the experimenter would close the book and instruct, “Now we’re going to see some of the things we saw before.” For each triad they were asked to select one of the novel items. For example, “Now we’re going to see a Toma. One is a Toma! Yeah! One of the things is a Toma!” “Can you *point* at the Toma?”

After the memory trials, children were presented with a color recognition test and were asked about the 9 target colors asked about during the learning trials. The colors were arranged in three tows of 3, each having its own square. The researcher would ask, “Show me yellow!” and wait for the child to point to a color square before moving on to the next color in the row.

The order that children see the object pairs and whether they are asked about the familiar or novel objects was counterbalanced. The order was counterbalanced through rearranging the sequence of trials to ensure that one novel-familiar pair did not appear in the same segment of the sequence more than once. Additionally, whether children were asked about the novel or familiar object was counterbalanced through a sequence generator that prevented a run of 3 familiar objects or novel objects.

Coding

Participants responses to the color question during the learning trials and their novel object selection during memory trials was coded from video tapes. In each trial, coders gave participants a 1 if they correctly identified the color of the target object and 0 if they incorrectly identified the color. Out of the total number of target objects labelled, participants could receive a high score of 24 if they correctly identified the object for each trial (12 for familiar items and 12 for novel items). Participants were also scored on their responses during the memory trials. Participants received a score between 0 and 4 for each of the 4 memory trials based on the number of correct trials. A research assistant coded the trials. Agreement between coders was 93% with strong interrater reliability (Kappa = 0.81).

Results

We first ran an ANOVA on immediate learning as measured by the participant's response on the color of the object during learning trials. For these analyses only children's responses to the novel label trials are analyzed. For the pointing and labelling condition, children chose words at a mean of 8.77 words with SD = 4.17. In the no pointing and no labelling condition, children chose words at a mean of 10.6 with an SD = 1.93. Our results showed no difference between conditions for target selection for the immediate learning trials, $F(1,18) = 1.515$, $p = 0.236$, $\eta^2 = 0.087$. We also compared children's selection of the target to chance levels (= 6). Our results indicated that children used the information they were offered to identify the correct test objects immediately at above chance, $t(17) = 4.779$, $p < .001$.

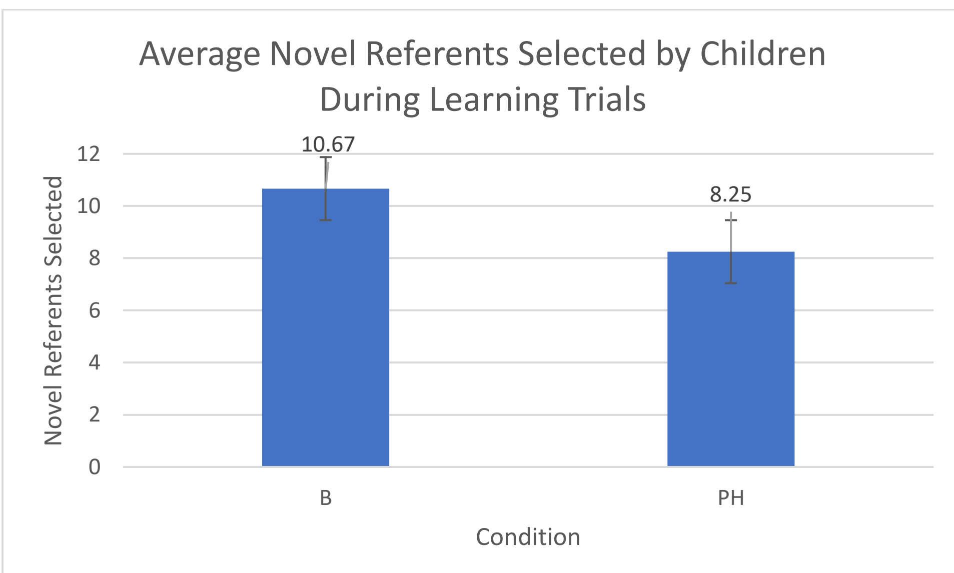

Figure 1: Mean Referents Identified in Each Condition, Prediction and Hypothesis Test (PH) & Baseline Condition During Learning Trials

To analyze if the children retained the correct referent after the immediate trials, we ran a one-way ANOVA test on their responding to the memory trials. Our results showed that there was no significant difference between the baseline and prediction and hypothesis condition, $F(1,18) = 0.003$, $p = 0.961$, $\eta^2 = 0.0001$.

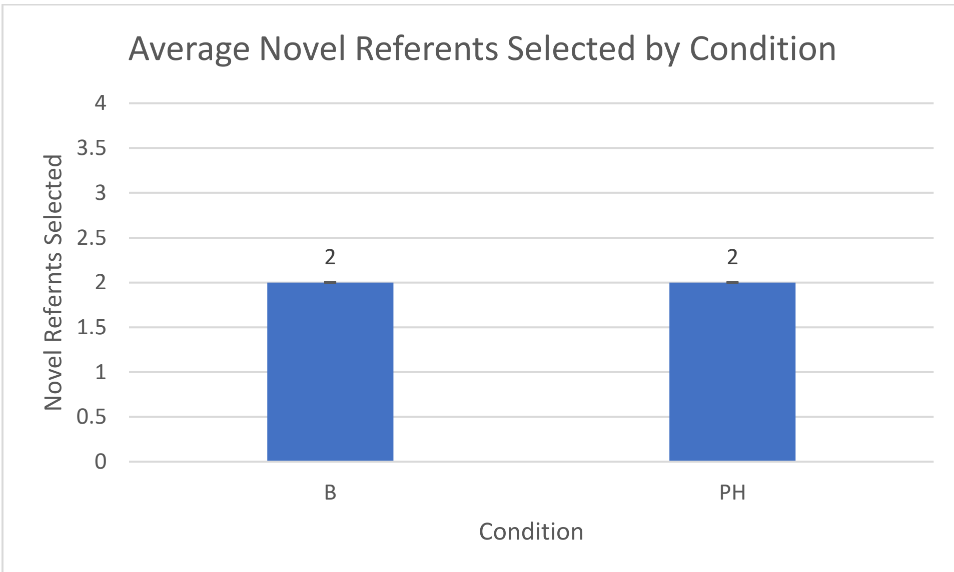

Figure 2: Mean Words Selected in Each Condition. Prediction and Hypothesis Test (PH) and Baseline Condition.

We further ran one-sample t-tests on the total words learnt in each condition to note the chance levels at which children learnt. Children's responding was trending to be above chance levels (1.33) in both the prediction and hypothesis condition ($t(9) = 2.241$, $p = 0.052$) and baseline condition, ($t(7) = 2.297$, $p = 0.055$).

Additionally, we ran a one-way ANOVA to further determine if the order of the presentation of objects and the position of the object on the page influenced whether the participants learnt words more effectively in one condition over another. We found similar results ($F(1,18) = 0.476$, $p = 0.787$, $\eta^2 = 0.166$) displaying no significant effect between the words learnt and the order of presentation of the objects. In fact, all orders displayed similar levels of words learnt across both conditions. In Order Set 1 we found no variation between levels, Order 1 (n = 9, M = 2.33 out of 4, SD = 1.291). In Order set 2, where the orientation of the objects on the page were flipped, similar results were seen, 2 (n = 9, M = 1.33 out of 4, SD = 0.577).

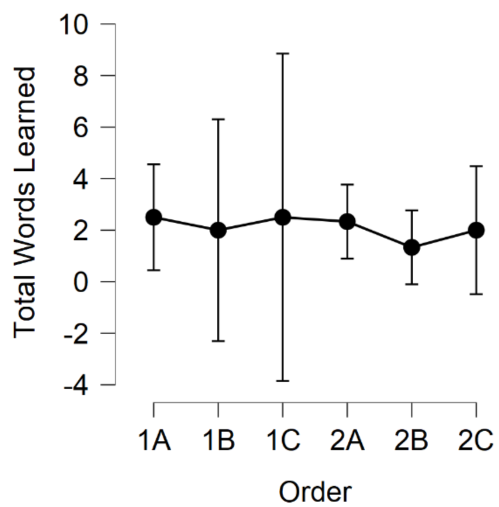

Figure 3: Mean Target Selected in Each Order

Discussion

This study investigated the efficacy of word learning in preschool-aged children when they were given the opportunity to make a prediction and test their hypothesis about what a word meant. We found that there were no significant differences between the conditions where children were induced to make a prediction and test their hypothesis versus when they were not. Children's showed above chance selection of target items immediately after receiving label information in both conditions. Their responding was trending to be above chance after a delay. There were no differences across conditions. This pattern of responding is most consistent with the results of Horst & Samuelson (2008). They found similarly, that while initial novel word referent is strong, children are similarly unable to retain the selected novel word after even a short delay. This suggests that 3-year-olds' word learning may be robust, incorporating a variety of strategies to learn words.

The results of our main analysis found that children's use of information and memory for new words did not differ across conditions. Moreover, children in neither condition showed reliable retention of the target words after a delay. One possible explanation for this result could be that the initial exposure to the novel object during learning trials was not enough to allow them to retain the word later on during the test trials. In this study, the main difference between the two conditions was the presentation of the label of the novel object. However, existing literature suggests that the process of retention improves significantly when children are provided time to interact with the novel object and familiarize themselves with it before it is named (Kucker & Samuelson, 2012). Future research could thereby focus on generating predictions and testing a hypothesis after children are provided ample time to familiarize themselves with both the novel and familiar object.

Another explanation that could explain the lack of a difference across conditions is the presence of competitor objects during the memory test. Since children were exposed to a variety of novel competitor and familiar competitor objects during the learning and the test trials, it is possible that this competition reduced their novel word retention. Earlier literature on the relationship between competitor objects and novel word retention suggests that children may need competition to support their word learning but have upper limits to the number of distractor objects present before word learning suffers (Horst & Samuelson, 2008). However, the nature of these competitor items is important; it is possible that since we named multiple novel items including the target items, children treated each novel item with equal ambiguity and thereby mis-assigned the variety of novel labels to novel objects. In fact, children are likely to accumulate a variety of mis-mappings and gradually disambiguate between the novel words as they are exposed to them (Yurovsky et al, 2014) suggesting that eventual retention may be difficult to reconstruct after initial exposure.

An additional reason children may have not shown evidence of retaining labels after the brief delay is that the format used to test memory of the labels was different (pointing at the target in a set of three possibilities) from the format that was used immediately (reporting the color the referent). This difference in format would result in children having to reproduce information that was encoded in a context they were not accustomed to and could thereby lead to weaker retention of the initial novel word. Furthermore, since the immediate test focused on reporting the contrast between two objects and the final between three, children were faced with a more challenging test than the initial trials had prepared them for.

A current limitation of the current study is the economic and cultural homogeneity in our sample. Almost all parents reported a household income of $75,000 or higher (95%) with only a few respondents (5%) reporting a household income of less than $75,000. A further 43% of parents reported incomes of more than $150,000. Our sample was further highly geographically localized and largely ethnically homogeneous (88% white). Our findings may not generalize to a more diverse sample. Previous research has revealed language processing differences by income (Pace et al., 2017; Schwab & Williams, 2016). Additionally, we asked children to point to objects they believed supported their prediction. This form of socio-pragmatic cueing varies greatly across cultures with regional and cultural differences playing a large role in the number of pointing cues offered by parents and infants (Liszkowski et al., 2012). Hypothesis testing as induced by pointing could thereby manifest in different ways across cultures and result in different levels of encoding and novel word retention. Future studies should include a more diverse sample to enhance generalizability of the findings.

The current study documented preschooler's novel word retention when induced to make a prediction and test their hypothesis versus when they were not. Future avenues for research could incorporate the potential ability to vary the number of competitor items, both familiar and novel, that children are exposed to during learning and test trials to note the subsequent effects on the retention of the novel word. Additionally, future research could explore the nature of the prediction and the eventual hypothesis test. Establishing a prediction by altering the order of the presentation of the novel information, perhaps by allowing more time to elapse between the presentation of the word and the presentation of the object could lead to a stronger association between the novel object and the novel label.

The focus of this study was to clarify the aspects of prediction-based learning by including in one study two conditions that allow children to induce a prediction and test their hypothesis by varying the timing of the information and the engagement with the novel information. It further informs the strategies children take when conducting immediate referent selections and the impact of these strategies on the retention of the novel association. Preschoolers learning and retention did not differ across conditions. Children used the information immediately as shown by robust identification of the correct item during initial exposure, but they did not show clear evidence of retaining the information after the delay. As the understanding of the exact process children use to learn new words comes into focus, it is crucial that educators understand the best ways children can learn new words. This would thereby allow them to design curriculum that best supports novel word learning, whether that be from more inductive learning or other techniques.

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