Journal of Experimental Child Psychology 109 (2011) 132–140

Contents lists available at ScienceDirect

Journal of Experimental Child Psychology

journal homepage: www.elsevier.com/locate/jecp

Brief Report

Rapid fast-mapping abilities in 2-year-olds

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ARTICLE INFO

Article history:
Received 31 July 2010
Revised 26 October 2010
Available online 8 December 2010

Keywords:
Fast mapping
Language acquisition
Retention
Referent selection
Mutual exclusivity
Word learning

ABSTRACT

Learning a new word consists of two primary tasks that have often been conflated into a single process: *referent selection*, in which a child must determine the correct referent of a novel label, and *referent retention*, which is the ability to store this newly formed label–object mapping in memory for later use. In addition, children must be capable of performing these tasks rapidly and repeatedly as they are frequently exposed to novel words during the course of natural conversation. Here we used a preferential pointing task to investigate 2-year-olds' ($N = 72$) ability to infer the referent of a novel noun from a single ambiguous exposure and their ability to retain this mapping over time. Children were asked to identify the referent of a novel label on six critical trials distributed throughout the course of a 10-min study involving many familiar and novel objects. On these critical trials, images of a known object and a novel object (e.g., a ball and a nameless artifact constructed in the laboratory) appeared on two computer screens and a voice asked children to "point at the _____ [e.g., glark]." Following label onset, children were allowed only 3 s during which to infer the correct referent, point at it, and potentially store this new word–object mapping. In a final posttest trial, all previously labeled novel objects appeared and children were asked to point to one of them (e.g., "Can you find the glark?"). To succeed, children needed to have initially mapped the novel labels correctly and retained these mappings over the course of the study. Despite the difficult demands of the current task, children successfully identified the target object on the retention trial. We conclude that 2-year-olds are able to fast map novel nouns during a brief single exposure under ambiguous labeling conditions.

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doi:10.1016/j.jecp.2010.10.013

Introduction

The study of fast mapping focuses on what children learn about a word after minimal exposure to a new label (for reviews, see Jaswal & Markman, 2001; Wilkinson & Mazzitelli, 2003; Woodward & Markman, 1998). The term *unambiguous* or *ostensive* refers to a naming act in which external cues (e.g., overt linguistic cues, cues from communicative intent) that direct children's attention to the correct referent are provided. Although behavioral cues carry with them their own challenges of ambiguity, experimenters have successfully elicited fast mapping by overtly drawing children's attention to the referent via pointing (Baldwin, 1993a; Leung & Rheingold, 1981), eye gaze (Baldwin, 1991; Baldwin, 1993b; Dunham, Dunham, & Curwin, 1993), or an explicit linguistic contrast (e.g., "Bring me the chromium tray, *not the red one*; I want the chromium one") (Carey & Bartlett, 1978). In the most extreme case, the correct referent is the only object present, making the referent of the new word quite clear (Au & Glusman, 1990; Baldwin, Markman, Bill, Desjardins, & Irwin, 1996; Booth & Waxman, 2002; Dickinson, 1984; Markson & Bloom, 1997; Waxman & Booth, 2000).

Recent work has extended these demonstrations of fast mapping to more ambiguous labeling acts, showing that 2-year-olds can learn as much about a new word from an indirect exposure as from an act of ostensive labeling (Jaswal & Markman, 2001; for related results, see Golinkoff, Hirsh-Pasek, Bailey, & Wenger, 1992; Mervis & Bertrand, 1994; Rice, 1990; Vincent-Smith, Bricker, & Bricker, 1974; Wilkinson & Mazzitelli, 2003). Work on fast mapping has also shown that children can retain a newly learned word for a significant amount of time following the initial encounter. In the original demonstration, Carey and Bartlett (1978) showed that children remember some semantic information about a novel label more than 1 week after a single encounter with it. Markson and Bloom (1997) extended this result and showed successful retention at delays of 1 month after the initial exposure to a single new word.

Although these studies have been integral to our understanding of fast mapping, many questions remain. For example, the connection between identifying the correct referent during learning (*referent selection*) and reidentifying it at test (*referent retention*) has received less attention. One recent contribution is a study by Horst and Samuelson (2008) in which 24-month-olds were exposed to eight novel object–label mappings during a referent selection task and retention for these mappings was tested after a 5-min delay. The authors found that although children succeeded during the initial referent selection trials, they failed to correctly reidentify the target during the delayed retention test trial. The difficulty of transitioning from referent selection to referent retention can be further complicated because children may hear multiple new words in quick succession. This challenge may be ameliorated with multiple exposures to a new word across trials (Mather & Plunkett, 2009) or multiple naming acts in a natural conversation.

In the most common experimental designs, children learn only a few object names or only one object name (Baldwin et al., 1996; Behrend, Scofield, & Kleinknecht, 2001; Dollaghan, 1985; Golinkoff et al., 1992), the novel label may be repeated many times (Au & Glusman, 1990; Markman, Wasow, & Hansen, 2003; Woodward, Markman, & Fitzsimmons, 1994), and the object being referred to is clearly indicated (Carey & Bartlett, 1978; Markson & Bloom, 1997; Mervis, Golinkoff, & Bertrand, 1994). If children rely on fast mapping to rapidly acquire new words, then they must be able to demonstrate successful learning under a wide range of conditions. A manipulation that has yet to be tested in a single experiment is whether children can use fast mapping to learn multiple novel words when each object and label is presented only once under ambiguous and time-constrained conditions (but see Horst & Samuelson, 2008).

We had two goals for our experiment: (a) to test the fast-mapping abilities of 2-year-olds under conditions that are challenging on a number of dimensions and (b) to investigate whether such conditions allow children to succeed at both the initial mapping of a novel label to a novel object (referent selection) and the retention of this mapping for use at a later time (referent retention). We presented children with six ambiguous referent selection novel label trials over the course of the study. On these trials, children saw a familiar object (e.g., a ball) and a novel object, and a voice on a computer asked them to "point at the _____ [e.g., glark]." Including the four practice trials, children saw 38 familiar objects and 12 novel objects, they heard 22 familiar labels and 6 novel labels, and each label was uttered only once in an ambiguous context over the course of a 10-min experiment.[1] We tested retention for the novel labels by presenting all six previously labeled novel objects and probing retention for one of them in a single posttest retention trial.

Method

Participants

Participants were 72 English-speaking 24- to 36-month-olds (38 boys and 34 girls, mean age = 30.08 months, *SD* = 3.25). An additional 28 children participated but were removed from the sample for parental interference ($n = 6$), refusal to point ($n = 7$), fussiness ($n = 3$), failure to complete training ($n = 7$), or experimenter/equipment error ($n = 5$). Participants were randomly placed in one of six conditions controlling for trial order and side of image presentation.

Procedure

Participants were seated in a sound-attenuated room facing two computer monitors that were 72 cm apart at their centers. Caretakers were seated approximately 4 feet behind the children, visible to the experimenter, and could not influence children's performance. The computer screens were surrounded by an opaque curtain that the experimenter stood behind to control the computer.

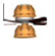
Visual stimuli consisted of 50 computer-generated three-dimensional objects from the TarrLab Object Data Bank (Tarr, 1996). An additional 12 images consisting of rare or unusual utensils and tools were used as the novel objects. For referent selection trials, objects were equal-sized (2.5 square inches) and displayed centered on 16.5-in. (diagonal) monitors, with one object on each monitor. These sizes were maintained throughout the study for consistency. Auditory stimuli consisted of 24 labeling phrases recorded by a native English speaker. The target label appeared in the sentential-final position after a carrier phrase (i.e., "Point at the _____"). Prior to beginning the study, parents filled out a vocabulary inventory consisting of the familiar objects used in the study. This was to ensure that children were in fact familiar with the known objects and labels, and it was not used as a standardized measure of vocabulary development.

The study included both a referent selection phase and a referent retention posttest trial. In the referent selection phase, children saw both familiar and novel objects in a version of the preferential looking paradigm (Fantz, 1963; Golinkoff, Hirsh-Pasek, Cauley, & Gordon, 1987; Spelke, 1976). On each trial, two objects appeared, with one object centered on each monitor. After a 2-s delay, the computer played a labeling phrase for one of the objects ("Point at the _____ [e.g., glark]"). After the onset of the label, children had a total of 3 s to infer which object was being referred to, point to this object, and retain this mapping for later recognition. The rationale for implementing this time constraint came from our previous work (Halberda, 2003; Halberda, 2006; Spiegel, Zosh, & Halberda, 2008), which suggests that it takes 2- to 4-year-olds approximately 3 s to determine the referent of a novel label and to point to this object in our experimental setting. Ending the trial 3 s after the label onset minimized children's opportunity to rehearse these newly learned object–label pairings, further challenging their fast-mapping abilities.

The study began with four practice trials that consisted of only known objects designed to familiarize children with the task. Once children were accustomed to the task demands, the experimenter explained that he needed to go behind a screen to start the game. This was done to ensure that the experimenter was blind to the trial order and could not see the objects or hear the labels during the course of the study. Six pseudorandom trial orders were constructed with the constraint that two novel label trials did not appear consecutively and that a target object did not appear on the same

[1] To gain a sense for how challenging this task may be for a 2-year-old, we encourage readers to view the sample trials given at http://www.psy.jhu.edu/~halberda/demos.html.

Table 1
Sample trial order.

Trial number	Left screen	Right screen	Instruction
1			"Point at the bed"
2			"Point at the scissors"
3			"This is a door"
4			"Point at the glasses"
5			"Point at the pizer"
6			"This is a pen"
7			"Point at the chair"
8			"Point at the glark"
9			"Point at the watch"
10			"This is a hat"
11			"Point at the blick"
12			"Point at the belt"
13			"Point at the car"
14			"Point at the tanzer"
15			"This is a knife"
16			"Point at the pumpkin"

(*continued on next page*)

Table 1 (*continued*)

Trial number	Left screen	Right screen	Instruction
17			"Point at the lorp"
18			"Point at the fork"
19			"Point at the cup"
20			"Point at the dax"
21			"Point at the bicycle"
22			"This is a clock"
23			"Point at the pencil"
24			"This is a spoon"

Note. Novel objects have been circled.

side (i.e., left or right screen) more than twice in a row. The objects and labels used are presented in a sample trial order in Table 1.

On 6 of the 24 referent selection trials, a novel object was the labeled target. On these critical trials, the distracter object was a familiar object for which children knew a name. These 6 trials were evenly spaced throughout the middle block of referent selection trials (see Table 1 for an example trial order). Although object images and labels were randomized across conditions, children in all conditions received novel target trials at the same points during the study (specifically Trials 5, 8, 11, 14, 17, and 20).

On the remaining 18 trials, a known object was the labeled target (e.g., a telephone). On 6 of these trials, a novel object appeared as the distracter object but was not named. The remaining 12 trials were evenly composed of 6 trials in which two known objects were shown and 6 trials in which only a single known object appeared. These six no-distracter trials were included to ensure that children adhered to the task demands and were not included in the final analyses.

After the conclusion of the learning phase, there was a short delay (lasting $\sim$ 1 min) before the retention test began. During this delay, the experimenter returned from behind the curtain and told children that he did not get to see the objects and that he needed their help in finding one object. The experimenter then displayed all six of the previously named novel objects, with three objects appearing on each monitor in a triangular array (counterbalanced for position). Presenting all six novel objects made for a challenging posttest trial in which it would be unlikely for children to guess the correct answer by relying solely on a one-step process of elimination. The experimenter then asked children to identify one of the previously learned novel objects by physically touching the chosen object on the monitor. The experimenter watched children physically touch this object, and the selected object was recorded and later cross-checked against the trial order that children had received to determine whether or not they chose correctly. Retention was assessed for only one of the six previous novel targets, randomly determined, with equal numbers of children tested for each of the six referent selection trial positions. Testing each child only once ensured that children's decisions would not be biased by successive test trials and, thus, would not alter the chance level of performance on a given trial.

Results

Pointing during referent selection was coded from videotape by observers who were blind to which screen depicted the target object. Coders scored each child's first point after label onset to either the target screen or the distracter screen. Preliminary analyses suggested no differences between the two types of known label trials (i.e., known distracter and novel distracter), and so these were combined as known label trials throughout analyses.

Referent selection

We first asked whether children succeeded during the referent selection phase of the study by analyzing whether children pointed correctly on both novel and known label trials at above chance levels (because two objects were present, chance = 50%). Only children who pointed to the target were scored as correct. Children who pointed to the distracter or failed to point were scored as incorrect. The percentages of trials on which children correctly pointed to the target object on known and novel label trials were compared with chance using a one-sample t test. Children performed significantly above chance for both known label trials ($M = 76.6\%$), $t(71) = 7.73$, $p < .001$, and novel label trials ($M = 59.7\%$), $t(71) = 2.19$, $p < .05$ (Fig. 1A). The trend of weaker performance on novel labels is commonly found in the literature. This result was likely driven by children who did not point rather than by children who pointed incorrectly given that children pointed incorrectly on only 14.3% of novel label trials, whereas they did not point on 44.5% of novel label trials.

Referent retention

With six objects from which to choose, chance performance on the referent retention trial was 16.67% correct pointing. A planned binomial test on the full sample of participants revealed that chil-

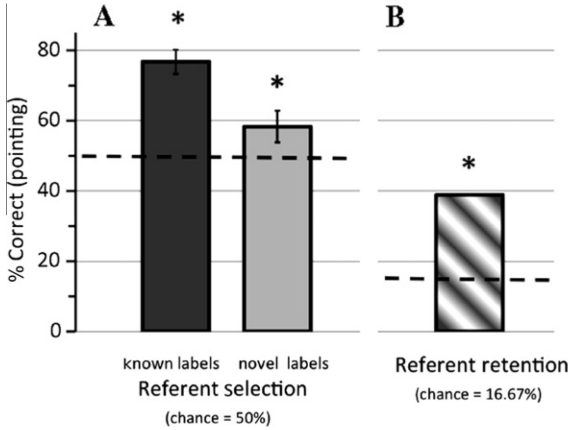


Fig. 1. (A) Percentages of trials on which children successfully pointed to the target when prompted with a known or novel label during referent selection (two-object display, chance = 50%). (B) Percentages of children who successfully pointed to the target novel object on the posttest referent retention trial (six-object display, chance = 16.67%). $^*p < .05$ (dashed line represents chance performance).

dren performed significantly above chance, with 39% of participants choosing the correct referent for the novel label, $p(x = .39) < .001$ (Fig. 1B). We conducted a follow-up chi-square test of independence to determine whether performance was contingent on the specific label–object pairing that served as the target. This omnibus test revealed a significant effect, $\chi^2(5) = 11.67$, $p = .04$, and a post hoc Z test comparing the standardized residual value of performance for each possible label–object pairing with the critical Z score of ±1.96 (for an alpha of .05) found that this result was due to greater performance for the label *glark*. This result was surprising given the prevalence of this label in the literature and the prior findings of no effect of label on performance. Importantly, we still found that a significant portion of our sample chose correctly on referent retention even after excluding data from all children who had been tested on the label *glark*, $p(x = .31) < .01$.

Next, we investigated the effect of delay between learning and test on referent retention performance. The delay between learning and test varied as a function of when children encountered the label on which they were tested. Children tested on the first novel label they heard had the longest delay between learning and test (3.5 min), whereas children tested on the last novel label they heard had the shortest delay (1.25 min). A chi-square test revealed that performance on this retention trial did not differ by position in which the target first appeared, χ^2 (5, 72) = 8.18 (Label 1: $M = .08$, $SE = .08$; Label 2: $M = .50$, $SE = .15$; Label 3: $M = .33$, $SE = .14$; Label 4: $M = .58$, $SE = .15$; Label 5: $M = .50$, $SE = .15$; Label 6: $M = .33$, $SE = .14$). Thus, our results suggest that children's success at referent retention in our paradigm did not vary as a function of delay between learning and test.

Lastly, we asked whether performance on the referent selection trial whose target later served as the target object on the posttest influenced performance at referent retention using a planned binomial test. On this referent selection trial, children could either correctly point at the novel object ($n = 33$), incorrectly point at the known object distracter ($n = 10$), or fail to point at either object ($n = 29$). Both children who pointed correctly, $p(x = .52) < .001$, and children who pointed incorrectly or failed to point, $p(x = .28) < .05$, succeeded on the posttest referent retention trial. Follow-up chi-square tests confirmed that although both groups were significantly above chance, children who pointed correctly during referent selection performed significantly better than children who pointed incorrectly or failed to point, χ^2 (1) = 4.09, $p < .05$, and that children who did not point were not significantly better than children who pointed incorrectly, χ^2 (1) = 0.02, $p = .88$.

Although this study was not explicitly designed to compare different assessments of learning, because performance had been coded frame by frame throughout the study, converging behavioral data were available, including the total percentage of time looking to target after label onset, the difference between baseline (prelabel looking) and postlabel looking to target, and the reaction time to point at the target. Each of these values was calculated for the referent selection trial that later served as the target object on the posttest using a series of chi-square tests of independence, which found that none of these measures was significantly correlated with performance on the referent retention trial.[2] This suggests that although estimates of performance during referent selection are important for understanding later retention, these estimates do not perfectly distinguish those children who will succeed from those who will fail.

Discussion

In the current study, we asked whether 2-year-olds can learn novel nouns from a single ambiguous exposure that lasts only 3 s. Our results demonstrate that despite the challenging conditions under which learning and testing took place (in terms of the large number of objects presented, the limited exposure to each object, and the lack of any reinforcement), a significant portion of the children in our sample were able to learn and retain at least one of the novel words they encountered during the course of the study. This finding adds to the existing literature by revealing that fast mapping is a robust process that is resilient under challenging conditions. Perhaps most important, we found a significant number of children who did *not* succeed during referent selection but nonetheless were above chance at referent retention, suggesting that learning is less absolute than a binary measure of point-

[2] A table showing these results may be found at http://www.psy.jhu.edu/~halberda/publicns.html.

ing (pointed correctly/did not point correctly) would lead one to believe. This finding challenges many assumptions regarding when learning has occurred and speaks to the need to find more sensitive measures of learning.

Because children were tested on only a single novel label during the referent retention posttest, it is impossible to say with certainty exactly how many of the six novel labels presented were retained by the children. However, given that children could not know which of the six critical novel labels would serve as the posttest target, it is unlikely that children succeeded in this task by retaining only the novel label that was later randomly selected for the referent retention trial. Therefore, it is likely that children retained more than one novel label encountered during referent selection (although it is unlikely that they retained all of them).[3]

Taken together, the current findings highlight that learning a new word is not an all-or-none process. Factors such as the delay between learning and test and the number or type of distracters present all contribute to whether or not children will demonstrate success during both the initial selection of the correct referent for a novel label and the retention of that mapping. In addition, the sensitivity of the outwardly observable behaviors used to operationally define success has a significant impact on the ability to assess when learning has taken place.

Acknowledgments

The authors thank Amelia Hritz, Miyuki Nishimura, and Xin Yuen for help in data collection and coding and also thank Amy Stocker for help in editing the manuscript.

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[3] This assessment is consistent with the findings of Horst and Samuelson (2008), who found that children could retain only up to four words.

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