Examining the incremental process of word learning: Word-form exposure and retention of new word-referent mappings

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Abstract: This study examines the process of learning new word-object mappings and how repeated exposure to word-forms impacts retention. Infants 18- and 24-months-of-age were first exposed to new word-object mappings in a referent selection task. To examine the influence of extra word-form repetitions on retention, newly mapped word-forms were repeated in a preferential listening task prior to a delayed retention test. Retention was tested in an object selection task. Consistent with prior work, infants performed very well on novel referent selection yet demonstrated a novelty bias on known referent selection trials that was especially prominent in the younger age group. There were no differences in listening times across age groups during the preferential listening task. However, there was some evidence that longer listening time predicted retention. As a group, 24-month-olds showed above chance retention of word-object mappings created during referent selection – an ability rarely seen at this age. This suggests additional exposure to word-forms after mapping may increase learning, at least in 24-month-old children. These findings both replicate prior work on children's referent selection abilities and highlight the incremental and cascading nature of the processes that strengthen new word-object mappings over repetition and development.

Keywords: referent selection; word learning; auditory familiarization.

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Introduction

Children make word learning appear quick, forming new word-referent mappings accurately and rapidly developing large vocabularies before reaching three years-old. However, learning even a single word is a time-extended process in which the mappings between word-forms and referents are strengthened over development (Carey, 2010). This process begins when a child first hears a word—in that first moment of exposure, the child must identify and encode the word-form from the speech stream and select the target from among multiple possible referents. This initial link, however, has been shown to be fragile: children often attend to the right object in-the-moment, but either fail to show evidence of retention a few minutes later (Bion et al., 2013; Horst & Samuelson, 2008) or show only limited retention in specific contexts (Axelsson & Horst, 2014; Kucker & Samuelson, 2012). In order to retain the new word-referent link, the initial mapping must be strengthened (Carey, 2010; Kucker et al., 2015). This can occur in a number of ways, including via repetition of the word-form, object, or word-object pair over exposures (McMurray et al., 2012; Mollica & Piantadosi, 2017).

For example, an associative computational model proposed by McMurray et al., 2012 (see also Kucker et al., 2018; Zhao et al., 2019) suggests that word-forms and objects are independently associated with conceptual or lexical representations (broader category of things to which the word-form might refer). In this account each subsequent exposure to a word-form, referent, or the pair, modifies the weights and connections between word-forms, referents, and conceptual representations in the lexical network, strengthening some connections and down-weighing or even pruning others. This means that relevant learning can occur both when a component of the mapping is not present, by reinforcing connections between that item (word-form or object) and the intermediate lexical layer (the nodes that connect word-forms and objects in the computational model), and by pruning spurious connections. Thus, mere exposure to a word-form or referent can reinforce individual connections, altering the network. Indeed, other work by Gathercole and colleagues (2006, 1997) suggests that the short-term memory of phonological forms (which are heightened with additional exposures) may play a particularly important role in word learning.

The current study probes this process, examining how a robust word-object mapping—one that can support longer-term retention—develops from real-time encoding, through repetitions, to retention. Notably, while our approach is based on an associative framework, the idea that repeated exposures are needed to solidify mapping is true of many other theoretical approaches (Carey, 2010; Hollich et al., 2000; Trueswell et al., 2013; Xu & Tenenbaum, 2007). For example, the propose-by-verify framework suggests that additional exposures either help infants verify or revise an initially proposed mapping (Trueswell et al., 2013). Thus, the current study aims to replicate and extend prior work on referent selection and retention by exploring how repeated exposure to auditory word-forms influences eventual retention at two ages (18- and

24-months). In particular, we hypothesize that repeated exposure to word-forms, particularly following an initial linking of a word and referent, may boost retention in the same way that prior work has shown to be true of object exposure (Kucker & Samuelson, 2012) or object-word pair repetition (Axelsson et al., 2012).

Developmental changes in word learning

Recent studies on word learning demonstrate reliable developmental changes in both in-the-moment referent selection and later retention abilities. For instance, as young as 14-months of age, children can identify a single referent of a single new word and retain it (Mervis & Bertrand, 1994). However, learning in more complex contexts with multiple competing referents shows an extended developmental trajectory that begins to emerge closer to 17-months (Lewis et al., 2020). In these paradigms (typically referred to as fast-mapping, mutual exclusivity, disambiguation, or referent selection), children are confronted with an array of objects, one of which is novel and the others familiar. They are then prompted with a novel word-form (e.g., get the cheem). In response, 17-month-old children look away from a known item and toward a novel object (Halberda, 2003). By 18 months, children can select the novel referent when prompted with a novel label (Bion et al., 2013; Horst & Samuelson, 2008; Kucker et al., 2018).

Thus, even young children can readily map novel word-forms to novel objects in-the-moment. But even at times when a correct initial mapping is not established, exposure to the word-referent pair can nonetheless create changes in the system that are the first step of learning. Indeed, work with both children and adult learners as well as computational models suggests that even when word learners choose the wrong item at first exposure, useful learning still occurs (Fitneva & Christiansen, 2011, 2017; Yurovsky et al., 2014). In one study, words that were not correctly mapped during initial exposure were subsequently mapped more quickly than brand new words upon a second exposure. This suggests that initial traces of learning were laid down at first exposure even if the behavioral responses did not show it (Yurovsky et al., 2014). Moreover, word learners encode information beyond the target during exposure, such as details of foil items and context (Wojcik & Saffran, 2013; Zettersten et al., 2018). Thus, even absent a correct referent selection, information about objects and labels that are simply present in the context is encoded by children in ways that can impact their future learning.

However, it is also clear that initial exposures are often not enough to support retention after a delay. For word-referent pairs encountered with competitors and named only once, retention is not robust until at least 30 months (Bion et al., 2013; Horst & Samuelson, 2008). Even past 30-months, mapping and retention continue to strengthen, supported by some of the same associative properties that direct attention toward the targets and away from distractors, strengthening and refining each associative path (Pomper & Saffran, 2019). Thus, children's ability to retain novel word-object mappings shows a rather protracted developmental course even in simple laboratory tasks. This process is likely to be especially pronounced from 18- to 24-months when vocabulary is exponentially increasing. Learning and retaining a new mapping requires that children form a robust representation of the object that is clearly distinguishable from other potential referents. They must form a similarly robust representation of the word form, and link both together. This system does not just rely on the exposure to the mapping (e.g., the word-form and object together) to achieve this robustness; rather research demonstrates that retention of new word-object mappings is also improved in the context of experiences that build stronger representation of the referents or word-forms alone (Vlach & Sandhofer, 2012).

The role of referent and/or label familiarity in retention

Associative learning is advanced through repeated exposure to word-forms and referents, either individually or together. A caregiver repeating word-forms in the presence of their referents can lead to learning that is usefully built upon in subsequent exposures, but exploration of unnamed objects and hearing words without referents can also build learning (see, e.g. Clerkin & Smith, 2022). Importantly, the relationship between objects and labels in this process does not need to be symmetrical (i.e. one does not necessarily learn objects and labels in equal ways or to equal degrees); recent work has shown that extra exposure to referents versus labels may impact word learning in different ways. Kucker and Samuelson (2012) demonstrated that even a short 1-2-minute familiarization with the referents of novel words prior to mapping boosted 24-month-old children's retention to levels higher than seen without familiarization. This suggests that familiarity with the referent supports stronger representations of the objects and has downstream effects on retention. This idea also fits with work by Clerkin et al. (2017) showing that the number of times infants have seen a referent, rather than heard its name, predicts which word-forms will be said first. Moreover, slightly older children (30-month-olds) who see multiple, variable, examples of the target object during referent selection retain the label for this new category (Twomey et al., 2014) as do similarly aged children given iconic or shape-based gestures alongside exposure to the label (Aussems & Kita, 2019; Capone & McGregor, 2005).

However, pre-familiarization with potential referents does not always improve performance. Kucker et al. (2018) showed that 18-month-olds given familiarity with novel referents prior to a single mapping trial did not show improved retention. This contrasts with the 24-month-olds of Kucker and Samuelson (2012) who benefited from familiarity, even with only a single mapping instance. One explanation for this is that for the younger 18-month-old children, referent selection is strongly driven by a novelty bias so robust that even a few minutes of familiarization does not diminish it (Kucker et al., 2018, 2020). Supporting this, these younger children fail to select *known* target items during referent selection when a novel foil item is present, even though they correctly select the same known items when no novel items are present. Together, these results suggest a shift in the impact of novelty and familiarity on referent selection and retention as children's vocabulary grows from 18- to 24-months. Moreover, object familiarity may have downstream effects on retention at older ages.

Other work suggests that exposure to auditory word-forms impacts subsequent learning. For instance, word-forms presented in isolation may prime word-referent mappings for toddlers (Willits et al., 2013), exposure to new phonological patterns influences the mapping of those sounds to objects (Breen et al., 2019) and in some cases, children's attention to auditory information may overshadow attention to visual stimuli (Robinson & Sloutsky, 2004). Moreover, word-form repetitions are frequent in the life of a child. Caregivers often use successive word repetitions in interactions (Schwab & Lew-Williams, 2016) and discuss absent objects (Gallerani et al., 2009), increasing a child's exposure to a word-form but without the referent. This is critical because auditory word forms are substantially different from objects. Whereas objects endure in time, word-forms are fleeting and need to be repeated to increase exposure.

This raises two central questions about toddlers' encoding of word-forms during referent selection tasks. First, how well do toddlers encode (and retain) the auditory word-form (independent of its referent) in the context of referent selection tasks when word-forms are heard once? Evidence suggests even young infants have this ability: 8-month-old infants retain repeated auditory word-forms for up to two weeks (Jusczyk & Hohne, 1997), and ten-month-old infants prefer pre-familiarized auditory stimuli (Robinson & Sloutsky, 2010), and recognize familiar words in speech (Jusczyk & Aslin, 1995). Further, work on toddlers' ability to discriminate mispronunciations of common words (Jusczyk & Aslin, 1995) and repeat novel forms presented in novel word representation tasks (Graf Estes et al., 2007; Hodges et al., 2016, see also Gordon et al., 2016 for evidence with 3-5 year-olds) suggests they quickly create auditory representations necessary for new word-object mappings.

However, less work has measured the robustness of these word-form representations in the context of word-object mapping, especially in children under 3-years. In many referent selection or fast-mapping studies assess learning by presenting the child with the word-form and asking them to select the referent (and not vice versa). However, children are rarely tested on their ability to retain the word-form independent of the mapping. One study with older children found that retention of new words by 3-year-olds was best supported by strong initial encoding, but that when newly learned mappings were lost, it was the word-forms that were most susceptible to decay (Munro et al., 2012). It is unknown if 18- to 24-month-old children's failure to retain new word-object mappings derives from the failure to form an auditory word-form representation if a word-form representation is formed but not linked to the referent, or if word-forms decay too quickly to support retention. What is needed is an independent test of word-form learning.

The second question is whether familiarity with word-forms promotes retention in the same way as object familiarity does. Literature on children's long-term episodic memory suggests it might—18-month-olds given verbal cues (narration of an event) prior to retrieval (but not during encoding) showed higher retention (Hayne & Herbert, 2004), and in the literature on memory in children, verbal cueing with task-relevant words can increase recall of prior facts and events (Bauer et al., 2007; Mateo et al., 2018). In each of the prior cases, children exposed to relevant verbal input performed better on subsequent memory tests. This suggests that retention of new word-referent pairs could theoretically be supported by word-form repetitions. However, few studies have tested this hypothesis on 18-24-month-old children who are in the midst of the vocabulary spurt. Studies that have, were limited to exposing children to word-forms *prior to* mapping, not after initial exposure.

In one example, Graf Estes, Evans, Alibali, et al., (2007) gave children an auditory statistical segmentation task (with no visual referents, but multiple repetitions of word-forms) prior to a referent mapping task. They found 17-month-old children were able to rapidly map novel objects to word-forms defined by high transition probabilities in the segmentation task. That is, by 17-months, exposure to word-forms may help with word-referent mapping, but its impact on retention is less clear. By 24-months, Kucker and Samuelson (2012) found that additional exposure to word-forms was not needed to aid in mapping—all children in this study reliably mapped new word-forms to referents regardless of exposure. However, word-form exposure did not improve retention at 24-months. Taken together, this work demonstrates there are developmental changes from 18-24-months in how word-form repetitions impact mapping, but the impact on retention is still unknown, especially for the younger children. Moreover, neither study tested the impact of word-form exposure after initial word-referent traces were laid down; a critical question given that initial mappings/exposures present the first step toward word learning. Thus, unknown is whether auditory familiarity after initial exposure may support retention in referent selection contexts, children's learning for word-forms, and at what ages such repetition may be beneficial for learning.

Current Study

Overall, the theoretical accounts and the literature suggest that repeated exposure may be helpful to support the retention of newly formed word-object mappings. However, while prior exposure to objects can boost retention of new mappings, the data is less clear with respect to the auditory component of new mappings. We know that infants can form initial auditory representations of word-forms heard in isolation. However, we do not know how well word-forms are retained from referent selection tasks or how repetition of word-forms impacts the process of word learning.

To examine these issues, we conducted a referent select and retention task, but inserted a probe of word-form encoding between referent selection and retention. A preferential listening task offered passive exposure to, and repetition of, the word-forms presented during referent selection. This task also provided a measure of children's recognition of word-forms from referent selection at this age (Willits et al., 2013). Multiple prior studies have used the referent selection and retention paradigm but without a preferential listening phase (Horst & Samuelson, 2008; Kucker et al., 2018); the study here paralleled those studies as closely as possible with the exact same stimuli, participant pool, and procedures used. This allowed comparison to similar groups of children who performed the same task without extra exposure to the word forms.

Our goals were three-fold. First, we used the preferential listening task to ask if children retain novel word-forms after initial exposure during the referent selection task. Second, we examined whether repetition of word forms after initial referent selection impacted later retention of word-referent pairs. Third, we examined how these effects change over vocabulary development by examining performance in two different age groups, 18- and 24-month-olds, selected because they had been the focus of the prior studies using the same paradigm and because the reviewed literature suggests ongoing changes in the processes supporting word learning in this period.

Methods

Participants

Two groups of children participated: 18-month-olds (N=33) and 24-month-olds (N=26), see Table 1. The sample size was based on prior work (e.g. Kucker & Samuelson, 2012) in which medium to large effects were found. Moreover, G*Power a priori power estimates for the ORs found in retention trials for Kucker & Samuelson (2012) suggest between 19-37 children would be needed to detect a large effect with a power of .95 in the current study. All children were monolingual English speakers and recruited from a Midwestern college town in the US. Ethnic/racial data and detailed SES information were not available for all children, but the majority for whom information was available identified as non-Hispanic, White and middle-upper class with at least one parent holding a college degree. Data for 3 additional children were dropped due to fussiness (2) and programming error (1). Informed consent was obtained prior to beginning the study and children received a small prize for participating.

The current sample was aimed to be representative of the population in terms of language ability and include children from the full spectrum of the curve. Although having a low expressive vocabulary (i.e. being a late talker) may be a risk factor for later developmental delays and DLD, simply being low on expressive vocabulary is far from a perfect predictor of later delays and many late-talking children catch-up to their peers and demonstrate normal vocabulary skills (Rescorla, 2011). Recent work has also suggested that there are no hard cut-off points for identifying a child as at-risk based solely on vocabulary size as vocabulary is a continuum (Dollghan, 2013; Kucker & Seidler, 2022). Thus, children with lower expressive vocabularies were not dropped from the current sample in order to provide a comprehensive assessment of this age, but children who were identified with significant developmental delays (e.g. autism, Down's syndrome) were excluded from participating in the first place.

Table 1. ***Demographics of sample***

Groups	N	Sex	Age	Expressive Vocabulary
18-month-olds	33	13 female	18; 26 (17;21-19;29)	81 (4-356)
24-month-olds	26	13 female	24; 18 (23;27-25;9)	300 (6-667)

Note, ranges shown in parentheses. Vocabulary according to total words on the MCDI-WS.

Stimuli

Two sets of objects were used during referent selection and retention: well-known familiar items and unfamiliar novel items (Figure 1). Labels for known items were known, on average, by 66% of 18-month-olds and 85% of 24-month-olds (LEX database; Dale & Fenson, 1996); novel items were unknown. All items were identical to those used in prior work (Horst & Samuelson, 2008; Kucker et al., 2018). Parents confirmed items were respectively known and novel and items were replaced as necessary. In addition, eight novel word-forms (from Horst & Hout, 2016) were used that conformed to the phonological rules of English but had no known referents (see Table 2). Four variations of each word-form (each clip 2 seconds long) were recorded in the experimenter's voice for preferential listening. Half of these word-forms were used in the Referent Selection (RS) trials and heard again in Preferential Listening and on the Retention trials; the other half were kept as novel and only heard in the Preferential Listening section. Order of trials were counter-balanced.

Figure 1. ***Known (a) and Novel (b) stimuli.***

Table 2. ***Novel Word-form stimuli***

Word forms	IPA	klattese	Phonotactic Probability	Neighborhood Density
Known				
Airplane	ˈɛɚˌpleɪ̯n	Erplen	.289	0
Banana	bəˈnɑːnə	b|n@nx	.311	0
Bed	bɛ́d	bEd	.162	22
Block	blɔ́k	blak	.158	4
Book	bʊk	bUk	.115	13
Bunny	bʌni	b^ni	.230	11
Cat	kæt	k@t	.238	27
Car	kɑɹ	kar	.232	17
Cow	kaʊ	kW	.102	9
Cup	kʌp	k^p	.169	12
Dog	dɔg	dcg	.086	7
Duck	dʌk	d^k	.145	7
Fork	foɹk	fork	.217	7
Hat	hæt	h@t	.185	25
Horse	hɔɹs	hcrs	.184	1
Novel				
Dite	dait	dYt	.152	19
Cheem	tʃîm	Cim	.090	8
Fode	foʊd	fod	.134	13
Lorp	lɔɹp	lorp	.198	1
Pabe	peɪb	peb	.140	6
Roke	ɹoʊk	rok	.153	19
Stad	stæd	st@d	.198	5
Yok	jɔ́k	yak	.122	8

Note, Phonotactic probability calculated from Vitevitch & Luce (2004). Neighborhood Density from child corpus from http://www.people.ku.edu/~mvitevit/PhonoProb-Home.html. Novel word-forms included both RS and NN words; which were RS and which were NN were randomized across children.

Procedure

The procedure for the warm-up, referent selection and retention phases were identical to that of prior work (Horst & Samuelson, 2008; Kucker et al., 2018). As in prior work, the child sat across a table from the experimenter in a booster chair or on their parent's lap. Parents were instructed to avoid interacting with their child, offering minimal, neutral encouragement only if needed. They completed the MacArthur-Bates Communicative Development Inventory: Words and Sentences (MCDI; Fenson et al., 1994) during the session, which was used to calculate total vocabulary size for each child. The procedure began with warm-up, then proceeded to the three phases of the test trials – referent selection, preferential listening, and retention (Figure 2). See online materials for full datasheets representing all objects, possible orders, and trials.

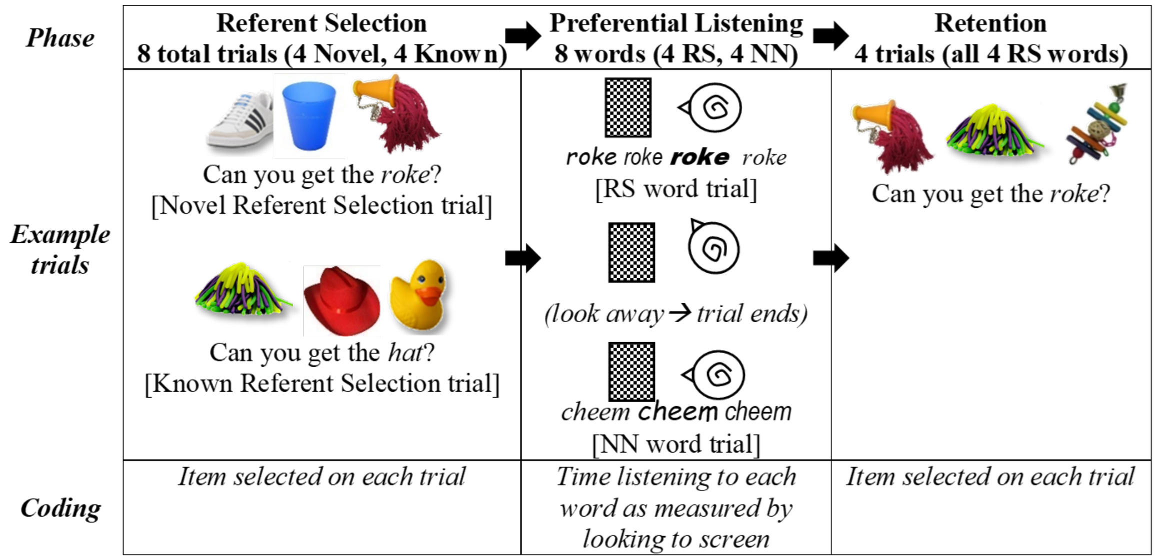

Figure 2. ***Schematic of the procedure***
Note: RS word-forms are those used on the novel referent selection trials, whereas NN word-forms are new novel word-forms presented only during preferential listening.

Warm-up

The warm-up period familiarized the child with the testing procedure. On each trial, three items were placed equidistant apart on a white tray. While maintaining eye contact with the child, the tray was placed on the table within view, but out of reach of the child, for three seconds. The experimenter then requested an item by name ("Can you get the hat?") and pushed the tray forward. Children were corrected or praised as needed (e.g. if the child chose the correct item, the experiment clapped and said, "Good job", whereas if the child chose the wrong item, the experimenter re-prompted once, then pointed to the correct answer). Target locations and prompts were randomized across trials and children, and each item was the target (with other familiar items as the foils) once for a total of three trials. Referent selection immediately followed.

Referent Selection

Referent selection consisted of eight trials with a similar procedure to warm-up, but without praise or correction. On each trial, two known items from warm-up and one never-before-seen novel item were present. On half the trials, children were asked to select a known item by name ("Can you get the hat?"); these are referred to as the Known RS trials. The other half of the trials (Novel RS) alternated and asked the child to select a novel item by name ("Can you get the roke?"). Children were prompted only once on each trial, consistent with prior work (Horst & Samuelson, 2008). Target items and locations were randomized across trials and children, and target items did not repeat.

Preferential Listening

Preferential listening took place in a curtained-off portion of an adjacent room immediately following referent selection. Children were seated on their parent's lap approximately 24" in front of a 42" flat screen monitor with speakers positioned on either side of the monitor. An infrared camera was positioned directly below the monitor and centered on the child. Auditory stimuli and a checkerboard pattern on the monitor were controlled via HABIT (Cohen et al., 2004). HABIT presents a simple, traditional habituation paradigm based on button presses by the experimenter to indicate the child is attending. The original HABIT software is now obsolete. However, an updated HABIT program is available from Oakes and colleagues (2019) that allows additional flexibility in software and stimuli. Parents wore headphones during the task to minimize interference.

The task began with five training trials using various sounds (e.g., bell chime, whistle). Using a head-turn procedure, a single sound was repeated as long as the child maintained attention at the screen displaying a black and white checkerboard pattern. Once the child turned away for two consecutive seconds, the trial ended, and a new sound was played following the same procedure.

Eight test trials immediately followed in the same manner using novel word-forms instead of sounds. To examine children's memory for word-forms presented during referent selection, we measured listening to both the novel word-forms heard during referent selection and to completely novel word-forms that were not previously presented during the study, with the expectation that a preference for one over the other would indicate learning. Head turns were recorded online by button presses from the experimenter and registered by the HABIT program.

This task tested four novel word-forms from referent selection (RS words) and four previously unheard new novel words (NN words). The specific words used for RS and NN were randomized across children. For each word-form, there were four different audio recordings produced by the same experimenter who conducted the referent selection phase. Clips were played in a random order. Order of test trials was randomized.

This procedure uses preferential listening as a test of recognition of the word-forms that appeared in the referent selection phase. Importantly, it also parallels the word-form familiarization procedure of Kucker and Samuelson (2012) in which the child, through their attention to the screen, chose which word-forms to hear again and how many times they would hear each word-form.

Retention

Retention immediately followed preferential listening. It was conducted in the same room as the warm-up and referent selection trials, using a similar task. Retention started with a single warm-up trial in the same manner as before to re-engage the child. To prevent repetition of referents, two retention trials followed (e.g. Horst & Samuelson, 2008). Each retention trial consisted of three previously seen novel items from referent selection: two items that had previously been named on a novel referent selection trial and one novel foil from known referent selection. Children were presented with all items on a tray as before and asked to select a single, previously-named item from a Novel RS trial by name ("Can you get the roke?"). No item repeated across the retention trials and the location and order of the target was randomized.

Coding

Children's final selections on referent selection and retention were coded by an experimenter blind to the hypothesis. See "choice" coding in online manual. Trials in which no item was a clear choice were marked as a no-response and not included in analyses. 40% of trials were recoded for reliability; agreement between coders was 100%. Experimenters achieved a 90% accuracy (via pre-recorded videos) on noting head turns in preferential listening prior to data collection.

Analysis

All referent selection and retention trials in which the child made a distinguishable choice were included in the analysis (>90% of trials). Preferential listening trials with less than 2000ms of listening (i.e. less than 2 repetitions of a word-form) were removed prior to analysis, as is standard in such tasks (Jusczyk & Aslin, 1995). A total of 27 (of 464) NN and 32 (of 464) RS preferential listening trials were dropped; all children had data from at least 2 (of 4) NN word trials and all but one child had at least 2 (of 4) RS word trials. The one exception was a child missing 3 RS word trials whose data was retained for the remaining word. One 18-month-old child missing retention data and one 24-month-old child without a completed MCDI were dropped from those respective analyses. Thus, all 59 children contributed data.

Generalized mixed models testing trial-by-trial performance and linear mixed models testing listening time were run separately for each experimental phase. Fixed factors included age-group (18- vs. 24-months-old, contrast coded respectively as -.5, +.5, then centered) as well as specific predictors relevant to the questions of each phase. In all cases, vocabulary was highly collinear with age (VIF's ≥5), so secondary exploratory analyses with models split by age group were run to examine the impact of vocabulary (centered) on performance (see Bion et al., 2013). Continuous predictors (vocabulary, looking time) were centered prior to inclusion as a predictor.

To assess performance in the RS and retention trials against chance, individual models for each age group were run with a random intercept of subject, and either a fixed effect of trial type (contrast coded; novel vs. known words for referent section), or no fixed effects (in the case of retention). Fixed effects were dummy coded with the trial type of interest set as 0 and the other as 1. The significance of the intercept was used to assess if accuracy within a condition was greater than chance (33%); because the default intercept assumes .5 as chance, an adjusted intercept was calculated by subtracting ln(1/2) (this value was used because chance was set to 33%: ln(.333/(1-.33)) = ln(1/2)) and dividing by the standard error to get a new Z score. A chance value of 33% was used here because children were given three items on each trial and prior work has suggested that children will consider all present items (Halberda, 2003); we had no reason to believe that children here would behave differently (indeed, as seen in the results, all objects present were chosen at least some portion of the time). Moreover, prior work with 3AFC paradigms, including those used as a comparison here, use 33% as chance (Gordon & McGregor, 2014; Horst & Samuelson, 2008; Warren & Duff, 2014).

Models were fit using R version 4.0.3 with the lme4 and lmerTest packages. We used the Laplace approximation for the glmer, and the Satterwaithe approximation to compute the degrees of freedom in lmerTest for linear models. The maximum random effect structure justified by the data was used according to AIC comparison (Seerdorff et al., 2019), which could include random intercepts and/or slopes of subject and item; in all cases a random intercept of subject was the best fit.

Results

Referent Selection

The goal of the referent selection trials was to test children's ability to select both a novel and a known item by name from an array. Mirroring prior work (Horst & Samuelson, 2008; Kucker et al., 2018), both age groups were well above chance at novel referent selection (Table 2, Model C; Figure 3): 18-months (96.05%, $p<.001$), 24-months (86.25%, $p<.001$), see Figure 3. These trials represent the initial exposure to the novel word-form as well as the first opportunity to link the label with a novel referent pair. Their behavior suggests that at a minimum, even young children's attention is directed toward the novel target when a novel label is present. This represents the children's initial exposure to the word-referent pair.

Table 2. ***Results of the models examining accuracy on referent selection trials***

Model & Predictors		***SE***	***Z***	***p***
A. Main Model				
Trial Type	1.444	.148	9.734	**<.001**
Age Group	.039	.162	.238	.812
Trial Type*Age Group	-.422	.134	-3.152	**.0016**
B. Follow-up models adding vocabulary (exploratory)				
18-month-olds				
Trial Type	1.715	.199	8.639	**<.001**
Total Vocabulary	.6596	.2240	2.945	**.003**
Trial Type*Vocabulary	-.546	.2244	-2.433	**.015**
24-month-olds				
Trial Type	.9473	.1894	5.001	**<.0001**
Total Vocabulary	.2359	.2155	1.095	.2737
Trial Type*Vocabulary	-.419	.185	-2.268	**.0233**
	adj	***SE***	***Z***	***p***
C. Performance against chance				
18-month-olds				
Novel Referent Selection	3.443	.398	8.651	**<.001**
Known Referent Selection	-.249	.258	-.967	.333
24-month-olds				
Novel Referent Selection	2.600	.331	7.867	**<.001**
Known Referent Selection	.695	.241	2.884	**.0039**

The variance for random effect of subject in Model A was .528, Model B 18mo was 0.00 and Model B 24mo was .322. Model C 18mo was .657 and 24mo was .417.
Note: Models C included only a fixed effect of trial type and a random effect of subject. Only the intercept, adjusted (βadj) to account for a chance level of 33%, was used to assess performance against chance.

However, performance on the known referent selection trials was not as strong. On the known referent selection trials, 24-month-old children accurately selected the target items above chance levels, 50.96% of the time, p=.004. Consistent with prior work (Kucker et al., 2018), younger 18-month-old children did not select known targets at levels different from chance, (33.09%, p=.333), instead selecting the novel foil item 67% of the time. Known foil items were only chosen 3% of the time. This suggests that children's responses to linguistic prompts can be swayed by the novelty or saliency of foil items (see also Pomper & Saffran, 2019), which may be due to the likely weaker prior knowledge in the younger group of children. This importantly replicates prior work showing that children perform well on novel referent selection, but that younger children can struggle to bring their vocabulary knowledge to bear in referent selection (Kucker, McMurray, & Samuelson, 2018).

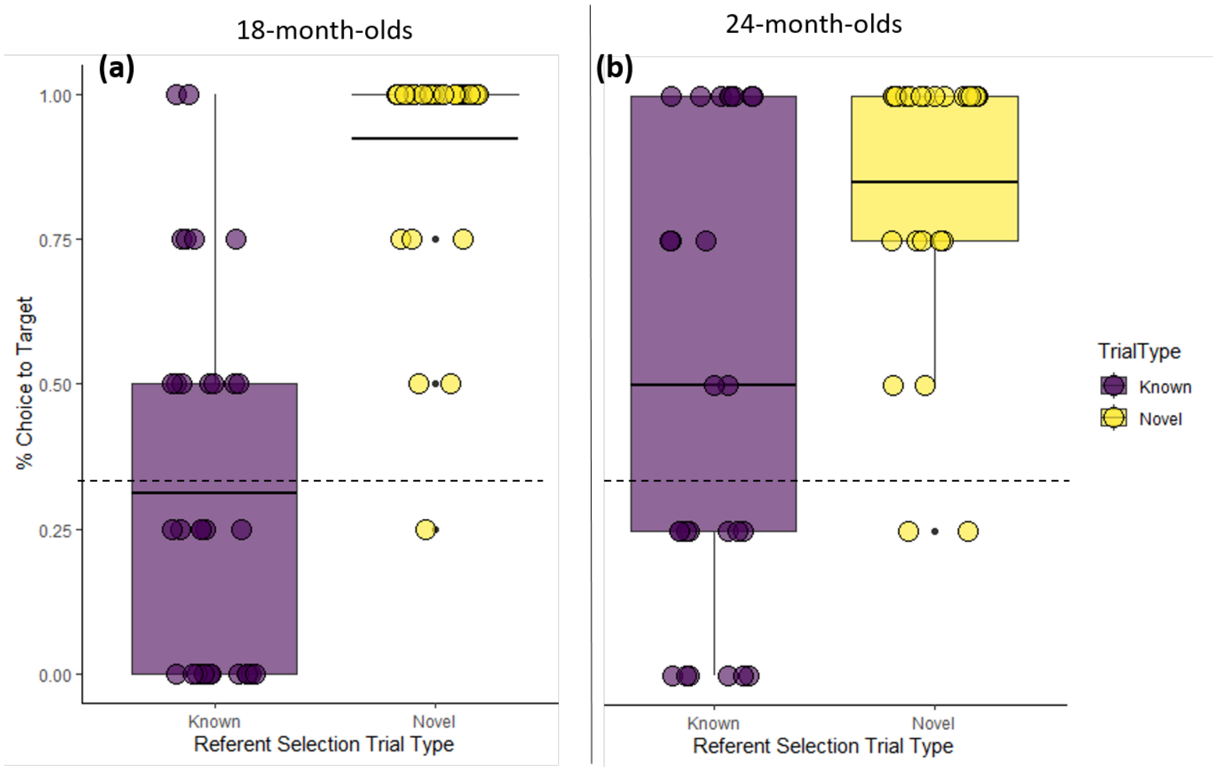

Figure 3. ***Average accuracy on RS trials for 18-month (a) and 24-month-old children (b).*** Dashed line represented chance (33%).

In order to further examine differences in performance by age group and across both trial types, a generalized linear mixed model (Table 2, Model A) of trial-by-trial performance was run with age group and trial type (Novel RS vs. Known RS, contrast coded respectively as +.5, -.5) as fixed factors. There was a significant interaction of age group and trial type as well as a significant main effect of trial type, suggesting that older 24-month-old children performed significantly better on the Known RS trials, but both ages performed equally well on Novel RS.

To understand the significant interaction, exploratory models were run for each age group, with trial-type and total vocabulary as fixed factors and a random intercept of subject (Table 2, Model B). The younger age group showed a significant effect of vocabulary and both ages showed significant effects of trial-type and significant interactions (Figure 4). In both age groups, children performed more accurately on Novel RS than Known RS and Known RS performance was positively correlated with vocabulary, but Novel RS performance was unaffected by vocabulary size (remained near ceiling).

Overall, performance on the Referent Selection trials mirrored prior work—children, regardless of age or vocabulary, accurately selected a novel item when given a novel

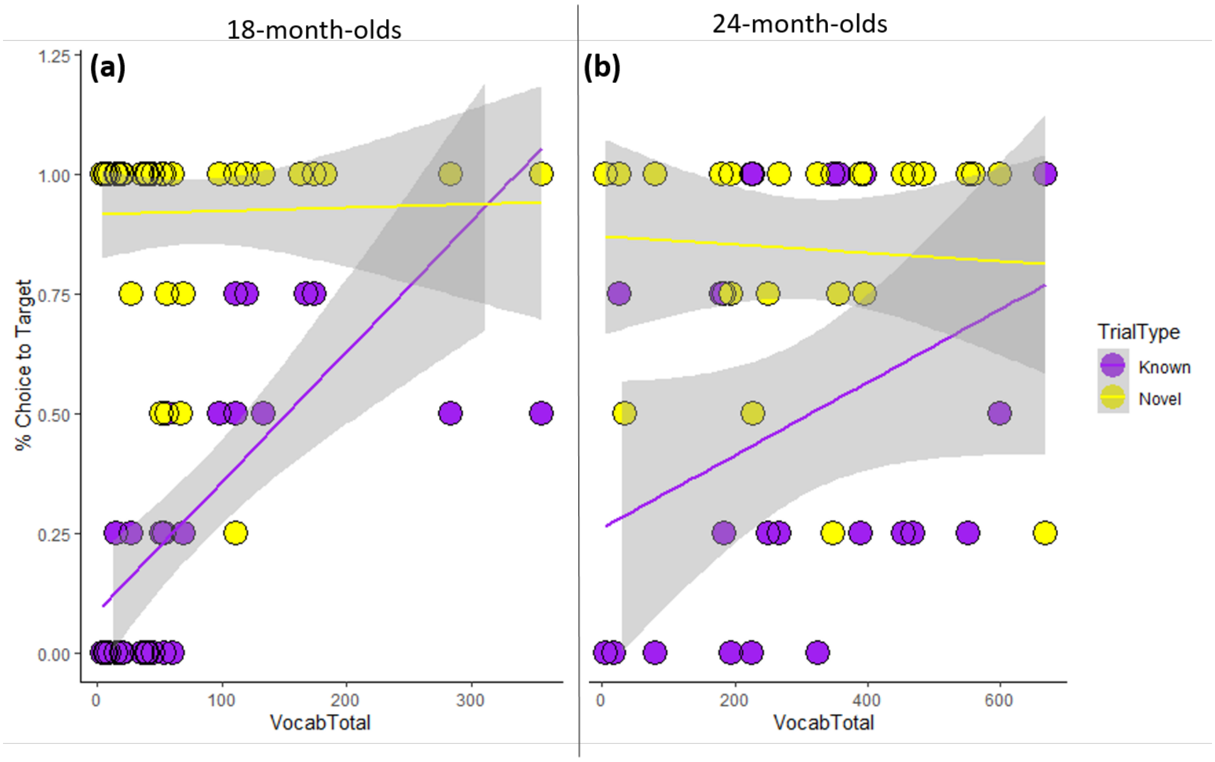

Figure 4. ***Correlations between average referent selection performance and vocabulary size for 18-month-old children (a) and 24-month-old children (b).*** Lines represent linear regressions and are for visualization purposes only.

label on Novel RS trials. Moreover, selection of a known item by name was predicted by a child's age (18-month-olds perform worse than 24-month-olds) and vocabulary (higher vocabularies perform better). Thus, real-time responding depends on the child's knowledge of the word (both form and referent) and their vocabulary level. Perhaps most pertinent is that the results here reproduce that of prior work (Horst & Samuelson, 2008; Kucker et al., 2018), showing differential performance between ages and trial types. The relatively poor performance of 18-month-old children on the Known RS trials is especially noteworthy as it calls in to question the mechanisms driving referent selection during Novel RS. Nonetheless, we know that exposure during these trials represent a critical first opportunity to lay down initial word-referent traces (McMurray et al., 2012), specially because children are clearly attending to the novel to-be-learned item (though if they also attended to the novel label is unknown, and one key question for the current study). Regardless of accuracy, at this point all children had been exposed to a set of known and novel word forms that co-occurred with specific referents (e.g., "cup" was heard when there was a cup present on the trial; "roke" was heard when its corresponding novel item was present). Thus, even if children did not select the correct item or did not listen to the label, it is still possible this exposure influenced their subsequent performance (Yurovsky et al., 2014).

Preferential Listening

The goals of preferential listening task were to 1) expose children to additional word-form repetitions before testing their retention, and 2) test children's memory for auditory word-forms. To assess preference for word-forms heard during referent selection (RS) compared to novel words (NN), a linear mixed model (Table 3) was run with age group and word-type (RS vs. NN, contrast coded as +.5, -.5). The best fitting model included a random intercept of subject.

Table 3. ***Result of the model predicting preferential listening performance***

Model & Predictors	***β***	***SE***	***t***	***p***
Word Type	-.0314	.0428	-.733	.464
Age Group	.166	.0960	1.727	**.091**
Word Type*Age Group	.0022	.043	.052	.959

Note: Random effect of subject variance was .346

There was a marginal main effect of age group (*p*=.091), suggesting 24-month-old children spent slightly more time listening overall to all word types, but there were no differences in listening by word-type or interactions of age with word type; see Figure 5. There was also no significant relationship between RS performance and listening time, see Supplemental Materials.

The lack of difference in listening times for RS words compared to NN words suggests that children could not differentiate between them and may not have retained the word-forms presented in the referent selection task. However, there was a lot of within child variability—individual children listened to some word-forms for only two seconds (only 2 repetitions of the word-form) and others for nearly a minute (up to 30 repetitions). Given that children in this study were slightly older than those in traditional head-turn tasks, this variability is not surprising. Familiarity vs. novelty biases are not always consistent in infants and can even be seen to switch from trial to trial, especially in children closer to this age (DePaolis et al., 2016; Fisher-Thompson, 2014; and see Mather, 2013 for a review). The within-subject variability thus likely obscured any potential evidence of word-form retention. As we describe further in the General Discussion, one possibility is children did learn words during Referent Selection, but that this preferential listening task was simply not sensitive enough to capture such learning. Another possibility is that children's representations of the novel words presented in the referent selection task were not robust enough to support differentiation between those words and new novel word-forms in the preferential listening task. These points notwithstanding, it is still the case that the preferential listening task provided the infants with additional exposure to the word-forms. Thus, we next asked whether this extra exposure impacted learning, and in particular if it supported retention of the new mappings.

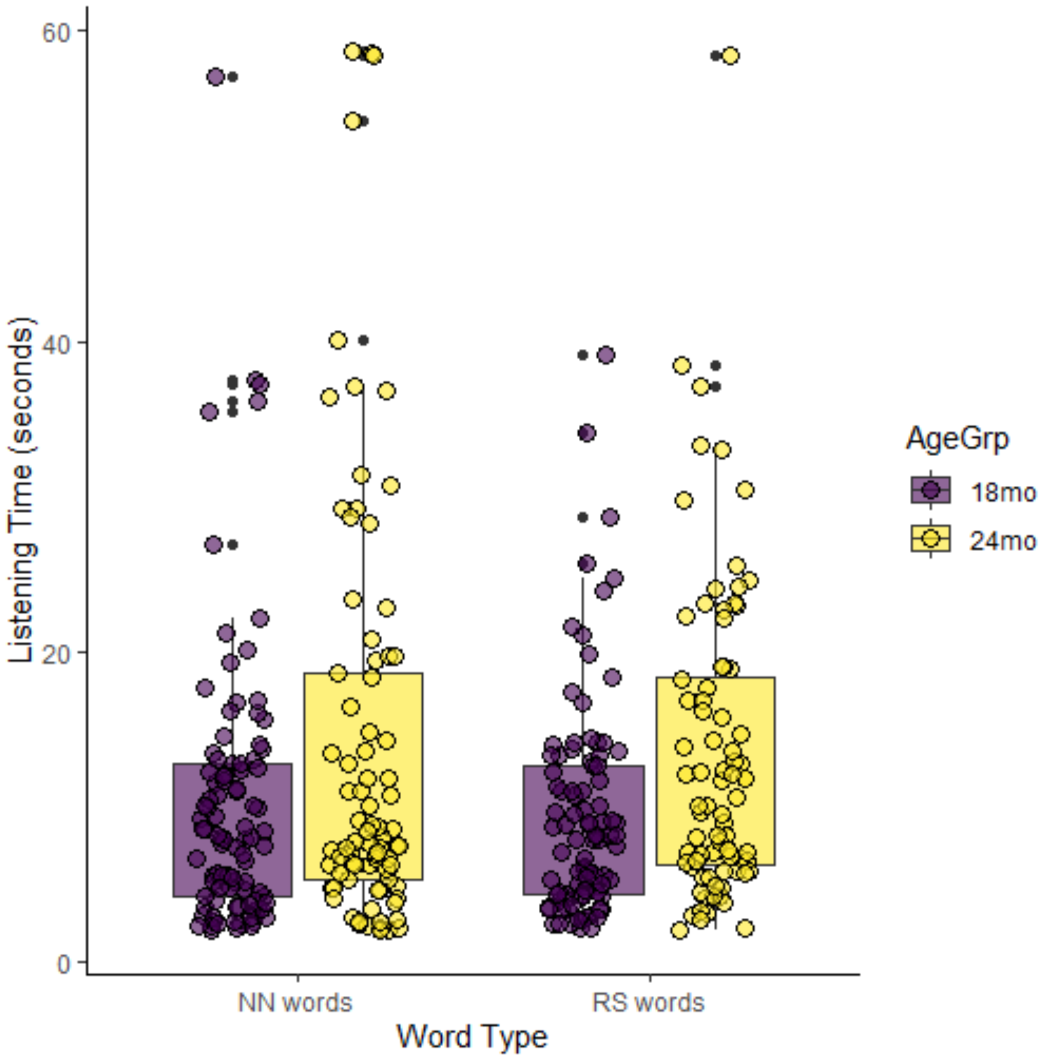

Figure 5. ***Listening time to NN words and RS words by 18- and 24-month-old infants***
Note: Points represent each child's listening for each individual word form (up to 8/participant), box represents mean listening time for each age group and word type.

Retention

The goal of retention was to ask if children recalled novel word-referent forms initially presented during referent selection. A key question is how retention was impacted by exposure to word-forms during the preferential listening phase. Consistent with prior work which found that 18-month-old children were at chance levels (33%) on retention trials (Kucker et al., 2018), 18-month-old children here were at chance on retention (40.3%, *p*=.245), suggesting they did not retain the novel word-referent pairs despite extra exposure. Children also chose the other named foil item at chance levels, 33.3% of the time, β_{adj}=0.00, SE=.26, z=.00, *p*=1.0, and the unnamed foil item the remainder of the time, demonstrating that they do consider all possible options available and showed no preference or evidence of knowing which items had labels.

However, contrary to prior work with 24-month-olds that had a retention rate of 36%, not significantly different from chance (Horst & Samuelson, 2008), 24-month-old children here were significantly *above* chance (54.9%, *p*=.0128; Table 4 Model B, Figure 6; see also Supplemental Materials Table S5). They also chose the other named foil item at levels significantly lower than chance, selecting it only 19.2% of the time, β_{adj}=.74, SE=.35, z=2.11, *p*=.035. Though there was no statistically significant effect of age group on retention (Table 4, Model A), 24-month-old children chose the labeled item more than foil items. Moreover, this is the same group of children who were marginally more likely to listen longer during preferential listening. This raises the possibility that additional exposures to multiple word-forms (both RS and NN) may have increased subsequent retention. However, further exploratory models predicting retention from a child's referent selection performance and/or listening preferences for specific word-forms were largely non-significant (see Supplementary material). Exploratory analyses (Table 4, Model B) suggested vocabulary was not a significant moderator. Thus, the retention effects are subtle, but noteworthy as they hint at one possible avenue for boosting learning of new words: repetition of word-forms.

Table 4. ***Results of the models examining retention performance***

Model & Predictors		***SE***	***Z***	***p***
A. Main Model				
Age Group	.317	.215	1.473	.141
B. Follow-up models adding vocabulary (exploratory)				
18-month-olds				
Total Vocabulary	.645	.5625	1.148	.251
24-month-olds				
Total Vocabulary	.0957	.342	.280	.779
	adj	***SE***	***Z***	***p***
C. Performance against chance				
18-month-olds	.301	.258	1.163	.2448
24-month-olds	.948	.381	2.488	**.0128**

Note: The variance for the random effect of subject for Model A was .319, Model B 18mo was 0.00, Model B 24mo was .874, and Model C was 0.00 for 18mo and 1.06 for 24mo.

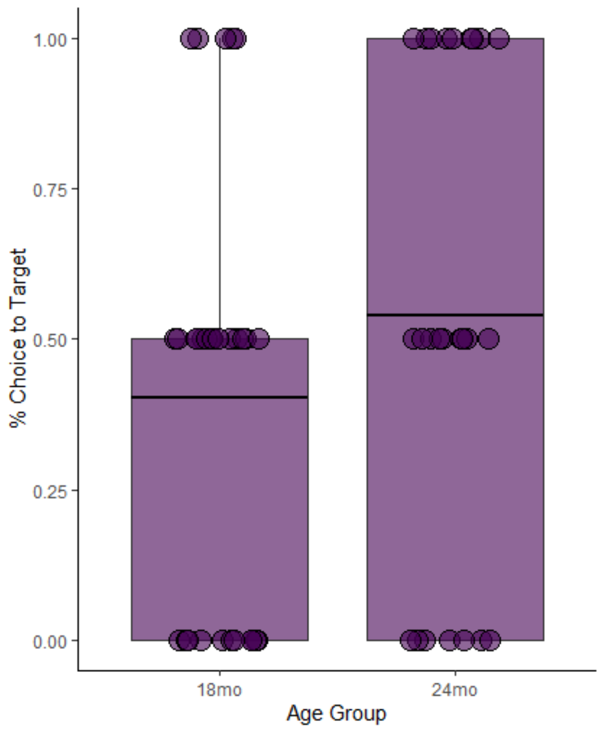

Figure 6. ***Average retention performance for 18- and 24-month-old children***

While the retention results were largely non-significant, they critically mirror prior work showing retention is very difficult at this age, and in particular that most children in this age-range do not retain words in this and similar paradigms (Bion et al., 2013; Horst & Samuelson, 2008; Kucker et al., 2018). However, 24-month-old children retaining words at above-chance levels shows possible evidence of downstream effects of word-form repetition on retention. While we did not find effects of individual words, it could be that general exposure to word forms hones the wider lexical network, thereby boosting retention without individual-level benefits. While these results should be taken with caution, they fit with theoretical accounts suggesting incremental changes in word-form representations from initial exposure to final retention for this age group.

Discussion

Word learning emerges over multiple cascading moments. A referent is selected in the moment after hearing a word-form and initial word-referent links are formed. These word-referent links are later reinforced and refined over exposures, ultimately leading to retention. The incremental nature of this process is partially supported by the current study. We replicated prior findings that young children reliably select novel referents on request but that 18-month-old children demonstrate a novelty bias when asked to select familiar, well-known referents. We also find support for the role of vocabulary in both known item selection and novelty bias by 18-month-olds.

While preferential listening did not reflect preferences for words presented during referent selection compared to new words (Goal 1), the 24-month-old age group (who performed better on the Known RS trials) listened marginally longer during the preferential listening phase. These older 24-month-old children also showed above chance retention after the additional exposure to word forms provided by the preferential listening task. This is notable as retention in this age group is not typically seen in similar paradigms without additional exposure (Goal 2). Neither of these last two findings held for 18-month-old children, suggesting possible changes in these effects during the period of early vocabulary development (Goal 3).

To learn a new word, a child has to make a robust association between a word-form and a referent but doing so is a time extended process. What is confirmed and replicated here is all children can easily select the novel referent when given a novel word-form, but younger 18-month-old children fail to select known referents when given a known name. Given that these younger children's vocabulary representations are likely less robust, this suggests that in-the-moment of referent selection strong novelty biases can override relatively weak lexical knowledge (see also Kucker et al., 2018). Thus, whatever novel words are mapped during referent selection may be driven by low-level perceptual processes and need additional reinforcement before supporting retention (see Mather, 2013). Indeed, 18-month-old children with high novelty biases did not show evidence of retention in the current study. As suggested by Kucker and colleagues (2018), the increased attention to novelty in referent selection may be a reflection of weaker lexical knowledge, and we know that children with weaker vocabulary skills have difficulty with mapping (Kucker & Seidler, 2022) and retention (Bion et al., 2013). This was likely true here as well as vocabulary was a significant predictor of RS performance in the 18-month-olds. However, vocabulary did not correlate with listening or retention, suggesting that at this age the strength of lexical knowledge may play less of a cascading, interactive role when it comes to word-form repetitions.

We hoped the preferential listening task would provide an intermediate test of word-form recognition, but there were no consistent differences in children's listening to word-forms from RS compared to novel words. However, there was also wide variability in listening times that likely masked systematic differences in memory. Preferences for novel vs. familiar words are known to shift between and within children in this age-range (DePaolis et al., 2016). In hindsight, interpreting preferential listening time as indicting "learning" is difficult (see also Cohen, 2004; Mather, 2013) especially at this age; does listening longer to the words from referent selection mean children did not finish encoding during RS, or does longer listening indicate they perceive the word-form as new? Differences in listening were thus ultimately not informative by themselves except to lend caution to future work using such a paradigm to capture differences at this age.

However, though it might be a weak measure of preference, the preferential listening task did allow individual children to control which word-forms they heard again. Children could self-select which word-forms they wanted more exposure to by continuing to look at the screen, much like the procedure used in Kucker and Samuelson (2012). As evidence of this opportunity, 24-month-old children did choose to listen slightly longer overall suggesting age differences in focus to auditory stimuli. We know that such additional exposure to word-forms can improve learning (Graf Estes, Evans, Alibali, et al., 2007; Hayne & Herbert, 2004) and indeed the 24-month-old group of children who listened more to the words from RS did demonstrate evidence of retention. Critically, retention for 24-month-old children here was at 51.3%, substantially higher than in prior comparison studies without a preferential listening period—in Horst and Samuelson (2008), 24-month-old children without familiarization showed 36% retention.

Thus, the results cautiously suggest the possibility that the extra exposures to word forms during the preferential listing task may have had downstream impacts on learning for some children. These results should be taken with caution though given the relatively small sample and limitations of the headturn preference task at this age. Moreover, it is important to point out that other work finds stronger benefits for additional object exposure. In Kucker and Samuelson (2012), children pre-familiarized with the novel objects retained over 70% of the time. The differential impacts of word-form and object familiarity are in some ways not surprising—word-forms are fleeting and harder to encode (Stager & Werker, 1997), more prone to decay over delay (Munro et al., 2012), and thus may require substantially more than just a half a dozen repetitions to have the same impact as one-minute of object familiarization. Indeed, other early word-learning work suggests that multiple exposures to the word-referent pair is necessary for robust mapping (Axelsson et al., 2012; Twomey et al., 2013); here children only heard the word-form and referent together once, which may also explain the spurious learning.

Alternatively, it is possible that referent selection, listening time, and retention are all related to a third individual difference factor that may be stronger in 24-month-old children compared to 18-month-olds. The literature suggests that vocabulary knowledge may be a possibility (Kalashnikova et al., 2016; Samuelson, 2021). However, given that neither listening time nor retention was related to vocabulary in the 24-month-old group, it is less likely that lexical ability is responsible here. This does not preclude other lower-level influences on word learning, however, and future work should further explore how attention, memory, and novelty play a role in word-form repetition and retention. One promising possibility is attraction to novelty which we know shifts over this same age range as vocabulary increases and executive function skills improve (Kucker et al., 2018; Samuelson, 2021).

Taken together, these results contribute to evidence of the moment-to-moment cascade of word learning and suggest that additional exposure to novel word forms after initial mapping may aid in retention. Variability between individual children in this process, and additional methodologies that can capture it, will be critical to examine in future work.

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Data, code and materials availability statement

De-identified participant-level data for preferential listening and referent selection, datasheets used for data collection, instructions for coding children's choices in referent selection, sound files used in preferential listening, and R scripts used for analysis are available at https://osf.io/9t8fk/. Images of items used as stimuli in referent selection are seen in Figure 1. The Editor agreed an exemption (3rd August 2023) to materials sharing for the MBCID as it is subject to copyright. It is available from the publisher at: https://brookespublishing.com/webcdi/

Ethics statement

Ethics approval was obtained from the ethics committee of the University of Iowa. All participants gave informed written consent before taking part in the study.

Authorship and Contributorship Statement

LKS and BM conceived of the study and jointly designed the study with SCK. SCK wrote the first draft of the manuscript, collected the data, and analyzed the results. LKS and BM revised the manuscript and aided in analysis. Funding for the project was provided by LKS. All authors approved the final version of the manuscript and agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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Supplementary Materials

Additional details pertaining to participants, data, analyses, and results are below.

Participants and data cleaning details

All referent selection and retention trials in which the child made a distinguishable choice were included in the analysis. Over 90% of trials were kept. All preferential listening trials in which the child listened for at least 2000 milliseconds were kept for analysis. For preferential listening, a total of 27 (of 464, 6%) NN and 32 (of 464, 7%) RS preferential listening trials were dropped; all children had data from at least 2 (of 4) NN word trials and all but one child had at least 2 (of 4) RS word trials. The one exception was a child missing 3 RS word trials whose data was retained for the remaining word. One 18-month-old child missing retention data and one 24-month-old child without a completed MCDI and were dropped from those respective analyses. Thus, all 59 children contributed data.

Additional Results

Additional exploratory analyses were run to examine the impacts of vocabulary and relations in performance across tasks. A final set of analyses compared the results here to that of prior work (Horst & Samuelson, 2008; Kucker et al., 2018), see Table S5.

Preferential Listening

In preferential listening, there were no differences in listening for word type; 18-month-old children listened to words from RS an average of 8.27 seconds (SD=4.55) and NN words 9.19 seconds (SD=6.49), 24-month-olds listened to RS for 11.34 seconds (SD=7.47) and NN words for 11.56 seconds (SD=10.28).[1] However, there was also significant variability in children's listening during preferential listening (Figure 5 in main text); given the already established variability in referent selection (RS) performance (Figure 4 in main text), this raised the question of whether listening time might be related to how children did during RS. That is, children who performed better during RS might have been expected to retain the novel word forms better. To test this, further exploratory analyses were run predicting listening time from prior RS performance (Table S1, Model B, below). This linear mixed model included fixed effects of accuracy on Known RS (centered), accuracy on Novel RS (centered), age group, and word type. The results were largely non-significant, however there was a marginal interaction of Age Group and Known RS. Analyses of vocabulary for each age group were also non-significant (Table S1, model C, below). Thus, there were no differences

[1] One word repetition was heard every 2 seconds. Thus, 18-month-olds heard RS words an average of 4 times and NN words 4.5 times, and 24-month-olds heard both RS and NN words an average of 5.5 times.

in overall listening times for type of word, and only a hint that individual older children who did better on Known RS may have listened to more word-form repetitions during this phase.

Table S1. ***Result of the model predicting preferential listening performance***

Model & Predictors	***β***	***SE***	***t***	***p***
A. Main model				
Word Type	-.0314	.0428	-.733	.464
Age Group	.166	.0960	1.727	**.091**
Word Type*Age Group	.0022	.043	.052	.959
B. Adding RS performance as predictor (exploratory)				
Novel RS accuracy	-.1887	.115	-1.648	**.107**
Known RS accuracy	.0383	.0626	.611	.544
Age Group	.157	.093	1.692	**.098**
Word Type	-.0204	.0434	-.469	.640
Novel RS*Age Group	-.0232	.116	-.201	.842
Novel RS*Word Type	-.0207	.0527	-.393	.694
Known RS*Age Group	.113	.062	1.829	**.0746**
Known RS*Word Type	-.033	.0295	-1.132	.259
Novel RS*Age*Word Type	-.001	.053	-.025	.980
Known RS*Age*Word Type	-.048	.029	-1.644	**.1013**
C. Follow-up models adding vocabulary (exploratory)				
18-month-olds				
Word Type	-.0425	.060	-.708	.480
Total vocabulary	-.0618	.135	-.458	.651
Word Type*Vocabulary	-.0422	.060	-.701	.484
24-month-olds				
Word Type	-.033	.0664	-.502	.617
Total Vocabulary	.0156	.151	.103	.919
Word Type*Vocabulary	-.035	.0667	-.519	.604

Retention

Children's ability to retain the novel word-referent mappings from referent selection were tested in the final phase of the experiment. In addition to the main effects of age group, exploratory analyses examined the impact of vocabulary size on performance (Table S2, Model A; Figures S1 and S2, below). A final set of analyses explored how preferential listening performance related to retention (Table S3, below).

Table S2. ***Results of the models examining retention performance***

Model & Predictors		***SE***	***Z***	***p***
A. Main model				
Age Group	.317	.215	1.473	.141
B. Adding RS performance as predictor (exploratory)				
Age Group	.224	.215	1.043	.297
KnownRS performance	.215	.147	1.468	.142
NovelRS performance	-.229	.258	-.887	.375
Age*Known RS	-.087	.142	-.616	.538
Age*Novel RS	.461	.254	1.815	**.070**[m]
C. Follow-up models adding vocabulary (exploratory)				
18-month-olds				
Total Vocabulary	.645	.5625	1.148	.251
24-month-olds				
Total Vocabulary	.0957	.342	.280	.779
	adj	***SE***	***Z***	***p***
B. Performance against chance				
18-month-olds	.301	.258	1.163	.2448
24-month-olds	.948	.381	2.488	**.0128**

Note: Models C included only a random effect of subject. Only the intercept (which was adjusted for chance at 33%) was used to assess performance in this model.

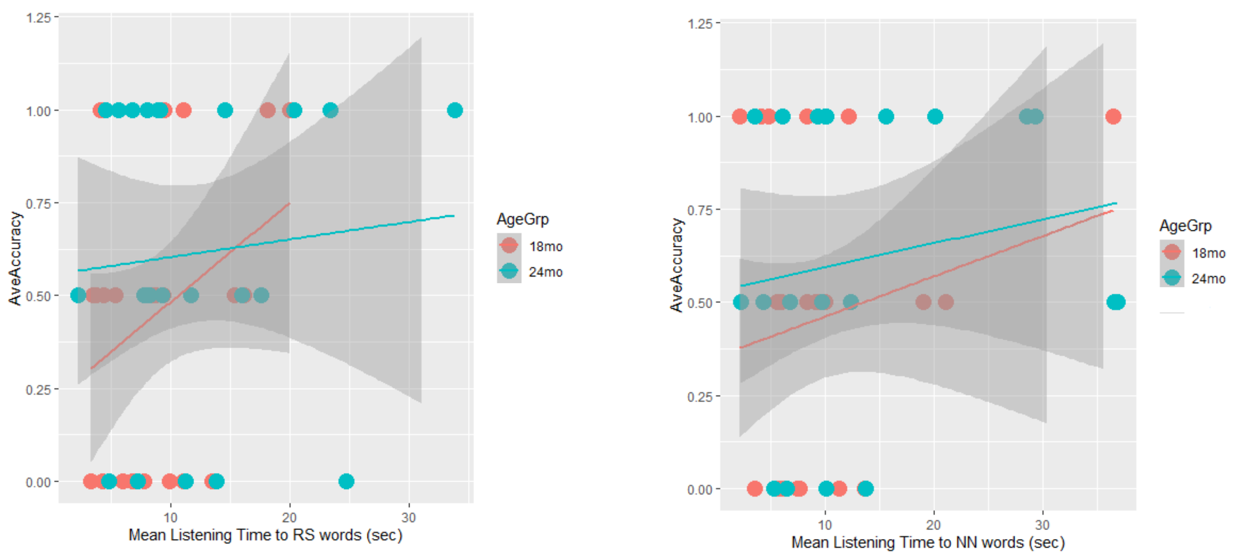

Figure S1. Average retention performance and listening time to RS words (left) and novel words (right), according to age group

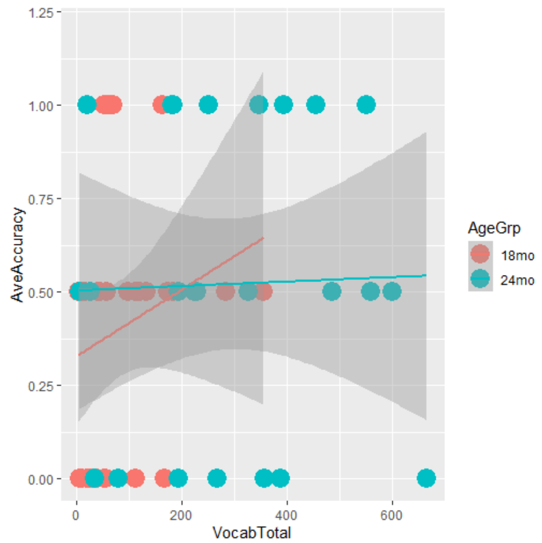

Figure S2. ***Retention performance as predicted by vocabulary size in 18- and 24-month-old infants***

Table S3. ***Results of the model predicting retention from Average listening preferences***

Model & Predictors		***SE***	***Z***	***p***
A. Predicting retention from average listening preferences				
Age Group	.2095	.2536	.826	.409
Ave RS listening time	.585	.721	.811	.418
Ave Novel listening time	.851	1.085	.784	.433
RS listening*Age Group	-.7663	.695	-1.103	.270
Novel listening*Age Group	.302	1.062	.284	.777
B. Follow-up models adding vocabulary (exploratory)				
18-month-olds				
Ave RS listening time	.825	.504	1.635	**.102**
Ave Novel listening time	-.174	.510	-.341	.733
Total Vocabulary	.440	.406	1.084	.279
RS listening*Vocabulary	.564	.545	1.035	.301
Novel listening*Vocabulary	-.901	.806	-1.118	.264
24-month-olds				
Ave RS listening time	-.927	1.237	-.749	.4454

Ave Novel listening time	3.269	2.229	1.467	.142
Total Vocabulary	-.343	.485	-.708	.479
RS listening*Vocabulary	.201	1.829	.110	.913
Novel listening*Vocabulary	-3.092	2.196	-1.408	.159
C. Predicting retention from listening time to specific words				
Age Group	.307	.240	1.278	.201
Listening time	.376	.3197	1.175	.240
Age Group*Listening	.073	.321	.228	.819
D. Follow-up models adding vocabulary (exploratory)				
18-month-olds				
Listening Time	.306	.369	.830	.407
Total Vocabulary	.252	.317	.795	.426
Listening*Vocabulary	.1995	.461	.433	.665
24-month-olds				
Listening Time	.306	.369	.830	.407
Total Vocabulary	.252	.317	.795	.426
Listening*Vocabulary	.1995	.461	.433	.665

Comparison with prior work

In order to compare to prior work using identical procedures but without a preferential listening period, between groups t-tests were run. The 18-months-olds of the current study were compared to that in Experiment 1 of Kucker et al. (2018) and 24-months compared to Experiment 1a of Horst and Samuelson (2008). There were no differences in 18-month-olds Known RS or Retention performance, though children here did perform better on Novel RS. For 24-month-old children, those here were marginally less likely to select the target on both Known and Novel RS trials (and both at levels still above chance). There was no difference in retention, though 24-month-old children in the current study were above chance. See Table S4, below.

Table S4. ***Proportion of correct trials***

	Known RS	Novel RS	Retention
18-month-olds			
Kucker et al. (2018), E1	.31 (.31)	.78 (.27)*	.33 (.36)
Current Study	.33 (.34)	.96 (.18)*	.36 (.35)
Between groups comparison	*t*(64)=.300, *p*=.765 [-.18, .14]	*t*(64)=3.231, *p*=.002 [-.29, -.07]	*t*(59)=.362, *p*=.718 [-.22, .15]
24-month-olds			
Horst & Samuelson (2008), E1a	.72 (.25)*	.69 (.18)*	.36 (.23)
Current Study	.51 (.42)*	.86 (.24)*	.51 (.41)*

Between groups comparison	*t*(40)=1.93, *p*=.061 [-.01, .43]	t(40)=2.644, *p*=.012 [-.30, -.04]	t(39)=1.35, *p*=.180 [-.38, .08]

Note: Means shown with standard deviation in parentheses. 95% CI for the t-test is in brackets. *indicates significantly different from chance (33%).

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