Journal of Memory and Language 141 (2025) 104596

Contents lists available at ScienceDirect

Journal of Memory and Language

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

Toddlers' looking behaviours during referent selection and relationships with immediate and delayed retention

Emma L. Axelsson [a,c,*], Jessica S. Horst [b], Samantha L. Playford [a], Amanda I. Winiger [c]

[a] School of Psychological Sciences, University of Newcastle, Australia
[b] School of Psychology, University of Sussex, United Kingdom
[c] Research School of Psychology, The Australian National University, Australia

ARTICLE INFO

Keywords:
Word learning
Toddlers
Eye tracking
Referent selection
Mutual exclusivity

ABSTRACT

The current study investigates whether children's attempts to solve referential ambiguity is best explained as a process-of-elimination or a novelty bias. We measured 2.5-year-old children's pointing and eye movements during referent selection trials and assessed whether this changes across repeated exposures. We also tested children's retention of novel words and how much focusing on novel targets during referent selection supports immediate and delayed retention as well as the effect of hearing the words ostensively named after referent selection. Time course analyses of children's looking during referent selection indicated that soon after noun onsets, in familiar target trials there was a greater focus on targets relative to chance, but in novel target trials, children focussed on targets less than chance, suggesting an initial focus on competitors. Children also took longer to focus on and point to novel compared to familiar targets. Thus, this converging evidence suggests referent selection is best described as a process-of-elimination. Ostensive naming also led to faster pointing at novel targets in subsequent trials and better delayed retention than the non-ostensive condition. In addition, a greater focus on novel targets during referent selection was associated with better immediate retention for the ostensive naming condition, but better delayed retention for the non-ostensive condition. Therefore, a focus on novelty may supplement weaker encoding, facilitating later retention.

Introduction

Acquiring new words is an important part of developing language skills (Gaskell & Ellis, 2009). Linking new words to objects is challenging as each word could refer to any number of objects, actions, or ideas (McMurray et al., 2012; Quine, 1960). Yet, in ambiguous contexts containing both novel and familiar objects, toddlers easily and quickly link a novel word to a novel referent (Halberda, 2003; Mervis & Bertrand, 1994). One explanation for this ability, referred to as fast mapping (Carey & Bartlett, 1978) or referent selection (e.g., Horst & Samuelson, 2008), is that toddlers rely on a mutual exclusivity assumption — that each object has only one name (e.g., Waxman & Booth, 2000), an assumption similar to lexical contrast (Clark, 1990), and the novel noun nameless category principles (Golinkoff et al., 1992; Merriman et al., 1995). These assumptions help to describe children's choices in ambiguous word learning contexts, but do not sufficiently explain the underlying mechanisms (Mather, 2013). One explanation is that children engage in a process-of-elimination during referent selection, ruling out familiar competitors to map novel words to novel objects (Axelsson et al., 2012; Halberda, 2003; Repnik et al., 2021; Spiegel & Halberda, 2011). Another is that children choose a novel target due to its novelty (e.g., Holland et al., 2018; Mather, 2013). More evidence on children's attention and encoding during referent selection is needed to disentangle whether referent selection is best explained as a process-of-elimination or a novelty bias. We also question whether this changes across repeated exposures and under conditions where children receive reinforcement for their selections. There are also mixed findings regarding the degree of attention to novel objects during referent selection and how much this supports retention (e.g., Bion et al., 2013; Booth et al., 2008; Kucker et al., 2020).

Encoding during referent selection and later retention

Measuring eye movements during referent selection can provide access to children's real-time interpretations of words and allow us to make assumptions about children's decision making (Fernald et al.,

* Corresponding author at: School of Psychological Sciences, University of Newcastle, Callaghan 2308, Australia.
E-mail address: emma.axelsson@newcastle.edu.au (E.L. Axelsson).

https://doi.org/10.1016/j.jml.2024.104596
Received 14 March 2024; Received in revised form 2 December 2024; Accepted 4 December 2024
Available online 12 December 2024

2008; Halberda, 2006). Children's looking proportions to targets across time can provide an indication of not only the focus on targets, but how it changes relative to a focus on competitors. Better understanding of what drives looking behaviours during the earliest stages of word learning could also highlight whether a focus on targets supports later retention.

Despite children's effective ability to disambiguate novel words, *retention* of multiple fast-mapped words is more difficult (Axelsson & Horst, 2013; Horst & Samuelson, 2008). Endogenous factors, such as attention to the target during the encoding stage could affect retention. A key aspect of the encoding stage is attending to a novel object while hearing a novel word (Wojcik, 2013), but it is uncertain if the degree of attention during encoding supports retention. Bredemann and Vlach (2021) argued that the speed and ease associated with referent selection might involve reduced attention to novel targets and inhibit retention. Relatedly, Bion et al. (2013) found that greater target looking proportions was associated with better retention in toddlers (see also Hilton et al., 2019; Twomey et al., 2018). However, Booth et al. (2008) found that target attention did not predict better retention even when they increased toddler attention through target manipulation (i.e., moving targets during labelling; see also Kucker et al., 2020). Therefore, more evidence is needed on the associations between target attention and retention of novel words and what this relationship looks like over longer time scales.

External factors during encoding can also affect retention. Axelsson and Horst (2014) repeated referent selection trials presenting targets with the same competitors, and Benitez and Smith (2012) presented targets in the same locations across trials. Both studies found faster target detection across trials and enhanced retention later. Repetition likely added a degree of predictability (Benitez & Smith, 2012), and ability to rule out competitors. Horst, Scott and Pollard (2010) also found better retention among 2.5-year-old toddlers who encountered fewer familiar competitors on referent selection trials. This is further evidence that conditions supporting a better focus on novel targets supports retention.

Feedback, such as repetition of the words, after the initial encoding stage can also affect retention (e.g.,Gurteen et al., 2011; Storkel et al., 2017). Ostensive naming is one form of feedback where the word is repeated while directing children's attention closely to the object and making it visually distinct from competitor objects. For example, Horst and Samuelson (2008) lifted and pointed to targets while naming them after each referent selection trial, and found enhanced retention of novel words among 2-year-olds (see also Axelsson et al., 2012; Vlach & Sandhofer, 2012). However, without ostensive naming, simple repetition of the correct mapping did not facilitate retention (Axelsson et al., 2012; Horst & Samuelson, 2008). More evidence is needed on the role of ostensive naming along with target attention during referent selection and how they relate to retention over longer time scales.

Differentiating between process-of-elimination and a novelty bias

Approaching referent selection from the perspective that children use a process-of-elimination to disambiguate makes two assumptions: first, that children know which referents are already associated with a name and which are not (Halberda, 2003); and second, that children attend to and rule out familiar competitors before selecting what they think is the target referent (e.g., Halberda, 2006). In contrast, from a novelty bias perspective, the novelty of the target drives children's selections (Mather & Plunkett, 2012). Therefore, according to the novelty bias perspective, there is little need to attend to the familiar competitors before making a selection. Mather (2013) argues that recognising each familiar object before identifying a novel referent is cognitively demanding and inefficient because the novelty of the target word and the novelty of the referent object is sufficient without needing to consider the nameability of the competitors. Thus, determining if and how much children attend to the familiar competitors after hearing a novel word will help us differentiate between these two accounts.

Halberda (2006) is consistent with the process-of-elimination account. In that study, when both adults and 3-year-old children were fixating on a target at the onset of a word (e.g., blick in "*Look at the blick*"), they shifted their gaze back-and-forth between targets and competitors on a greater proportion of novel target trials than familiar target trials. This looking pattern even occurred when the participants had already seen both the target and competitor prior to noun onset, that is, when it should be unnecessary to check on the competitor object. Shifting their gaze between the target and competitors at the onset of the word also led to the children and adults taking longer to point in the novel than in the familiar trials. Thus, Halberda (2006) argued, based on these converging pieces of evidence, that lexical knowledge and assessment of competitors is an important step during referent selection. Other studies have found better referent selection accuracy among toddlers who could spontaneously name competitor objects rather than only comprehend their labels, suggesting that lexical knowledge of competitors improved toddlers' capacity to rule them out (Grassmann et al., 2015; but see Kucker et al., 2020). More recently, Hilton et al. (2019) found greater than chance looking at familiar targets during referent selection, but chance level looking at novel targets suggesting more diffused attention across objects during novel target trials.

Mather (2013), who instead argued for a novelty bias, where children link novel words with novel objects with little need to consider familiar competitors, also notes a confound in referent selection studies, specifically that novel targets are often *both* novel and nameless. Several studies have explored this confound with children between 10 and 30 months of age. A study with 10-month-olds, who were yet to acquire familiar competitor words, found that they looked longer at the novel target than familiar competitor (particularly towards the later portion of trials), suggesting that at lower levels of vocabulary size the preference for novelty is based more on cognitive than language constraints (Kucker et al., 2020; Mather & Plunkett, 2010). Similarly, Mather and Plunkett (2012) found that, relative to previously seen novel objects, 22-month-old toddlers looked longer at a completely novel object when presented with a novel word (e.g., "*Look at the Gub!*"). Toddlers in that study were also faster to demonstrate a novelty preference in the context of familiar competitors. In an object selection task, Horst et al. (2011) observed that when all objects present are nameless (i.e., novel), toddlers will choose the most novel object as a referent of a novel word relative to recently familiarised novel objects (for a similar finding see also Holland et al., 2018). In sum, there is a developmental effect that is linked with the development of children's lexicon such that with an increasing vocabulary size, referent selection likely shifts from cognitive to more linguistic constraints. The studies above demonstrate that toddlers also use novelty to solve disambiguation trials, but neither study tested children's retention. Thus, it remains unclear whether a novelty bias during disambiguation affects later retention.

Current Study. In the current paper we explore toddlers' looking behaviours during referent selection to disentangle whether children solve referential disambiguation by using a process-of-elimination or relying on a novelty bias. Our other key aim is to better understand whether a focus on novelty supports later retention. We randomly assigned children to either an ostensive naming or non-ostensive naming condition to assess the effect of reinforcing children's attention to target objects following the initial encoding phase on immediate as well as delayed retention. We tested 2.5-year-old children to extend the findings of previous referent selection studies with novel targets (e.g., Bion et al., 2013; Golinkoff et al., 1992; Heibeck & Markman, 1987; Horst, 2011). Children completed two blocks of referent selection trials and we measured children's looking proportions to the target objects relative to two competitors in each trial to determine if attention to targets changes across trial blocks. For consistency with previous referent selection studies that included overt behaviours (e.g., reaching toward, picking up, and pointing to target objects), we also asked children to point to the target objects (e.g., Halberda, 2006). Relative to familiar target trials, in novel target trials, if children engage in a process-of-elimination, they should spend more time looking at familiar competitors and consequently their target looking proportions should be lower and they should take longer to point to targets (see also Hilton et al., 2019). In contrast, if children's behaviour is driven by a novelty bias, they should spend more time looking at novel targets relative to the familiar competitors. However, this alone would be insufficient in supporting a process-of-elimination account. We also assessed the time course of all the children's target looking to determine *when* they focus longer on novel targets relative to familiar competitors. With these analyses, we expected an *initial* focus on familiar competitors prior to an increase in novel target looking in novel target trials. In the second block of trials, we predicted faster target selections and higher target looking proportions as the novel objects become more familiar – particularly for the ostensive naming group who received feedback after each trial.

Few studies have considered the effect of attention to targets during referent selection on retention over longer time scales. We assessed how much children's target looking proportions relative to familiar competitors during referent selection relates to immediate retention, retention four hours later, and retention the following morning. As greater target looking proportions are associated with better retention (Bion et al., 2013; Wojcik, 2013), we hypothesised that this would support both better immediate and longer-term retention, especially for children who received ostensive naming (e.g., Axelsson et al., 2012) as it guides children's attention in early encoding.

Method

Participants

A power analysis performed with G*Power (with 7 predictors, power $= 0.85$, $\alpha = .05$, effect size $f2 = .25$ based on Horst et al., 2020; Twomey et al., 2014) revealed that 72 participants were needed (but see below for power with extra predictors). The final sample included 72 typically developing monolingual children (34 girls, 38 boys, M age $= 30.28$ months, $SD = 1.32$, range $= 28.07$ – 32.89 months) with 36 in the ostensive naming group and 36 in the non-ostensive naming group. Additional children were excluded from the analyses for difficulties with the pointing task (ostensive $n = 3$; non-ostensive $n = 7$), fussiness/inattentiveness (ostensive $n = 2$; non-ostensive $n = 2$), and eye tracking issues (ostensive $n = 2$; non-ostensive $n = 4$). Two children in the non-ostensive naming group did not point during the immediate retention test and were excluded from the retention analyses aside from their gaze data in the immediate retention test. Otherwise, all children completed all the delayed test trials. All children had normal vision. Vocabulary size did not differ significantly between children in the ostensive ($M = 467.14$, $SD = 80.61$) and non-ostensive groups ($M = 469.23$, $SD = 76.23$), $t(69) = 0.11$, $p = .911$, $d = 0.03$; as was also the case for gender, Fisher's Exact test, $p = .238$ (ostensive: 39 % female, non-ostensive: 56 % female); but they did differ in age, with the ostensive group older by 30.08 days, $t(70) = 3.76$, $p < .001$, $d = 0.89$ (ostensive: $M = 30.82$ months, $SD = 1.43$; non-ostensive: $M = 29.74$ months, $SD = 0.96$). Therefore, we included age and an age-by-group interaction in the analyses. Due to the addition of these two predictors our post-hoc power was 0.80. The children's mothers' mean age was 35.19 years ($SD = 5.28$) and they had 17.49 years in education ($SD = 2.40$); and fathers' mean age was 37.21 ($SD = 7.88$) with 16.57 years in education ($SD = 3.22$). The ethnicity of the mothers was white Australian (92 %), white European (4 %), and Australian Asian (4 %). The ethnicity of the fathers was white Australian (93 %), indigenous Australian (1 %), white European (4 %), and South African (1 %). Participants were recruited via posts on social media and flyers at childcare centres, cafés, and libraries. Data are available on the Open Science Framework https://osf.io/6yvdw/.

Apparatus and materials

Stimuli. Fifty-eight images of familiar objects (e.g., tree, shoe) were presented across warm-up and referent selection trials. These images were sourced from the Bank of Standardised Stimuli (Brodeur et al., 2014) and Shutterstock.com. The familiar words were chosen as they are known by at least 50 % of Australian children according to the Australian English Developmental Inventory (OZI, Kalashnikova et al., 2016). For the novel objects, four images of unknown objects and novel words were sourced from the Novel Object and Unusual Name (NOUN) Database (Horst & Hout, 2016). The novel words were all monosyllabic: cheem, hux, kiv, and noop. The images were presented on a 24-inch Dell monitor (1920 × 1080 resolution) and all images were on average of 77.11 mm × 65.99 mm (7.35° × 6.30° at a 60 cm distance). Interest areas (IAs), not visible to children, were positioned around each image for later extraction of fixation data. The IAs were all the same size, and were sized to fit all objects (see Figs. 1 & 2).

A female native speaker of Australian English recorded auditory instructions with an AKG C4000 microphone. The audio files were edited in Pro Tools 12 to ensure consistency in sound level, tempo, and duration.

Eye tracking. Children's fixations were recorded with an EyeLink 1000 system using a 16 mm lens and a sampling rate of 500 Hz and 0.5° spatial accuracy. A high contrast sticker placed above the child's right eye aided in gaze capture. Children sat on a caregiver's lap 55–60 cm from the camera and 60–65 cm from the display screen. The camera was desktop-mounted in front of and beneath the display monitor using the remote setting which allows for participant movement in an area of 22 cm × 18 cm × 20 cm. The images were presented using Experiment Builder software (1.10.1630; SR Research). Eye tracking data was extracted using Data Viewer software (4.2.1).

Design and procedure

Ethical approval was obtained from the Human Research Ethics Committee at The Australian National University (Protocol Number 2015/078) and caregivers provided written consent.

Warm-up. Toddlers at 17 months (Mervis & Bertrand, 1994) and 2 years of age (Spiegel & Halberda, 2011) are capable of successful referent selection via pointing, but we first provided three warm-up trials with familiar objects (e.g., train, spoon, elephant) using A3 posters on a wall to familiarise children with the pointing task. The experimenter praised children's correct choices or provided guidance for incorrect choices.

Additional Warm-up. Once seated in front of the eye tracker, three

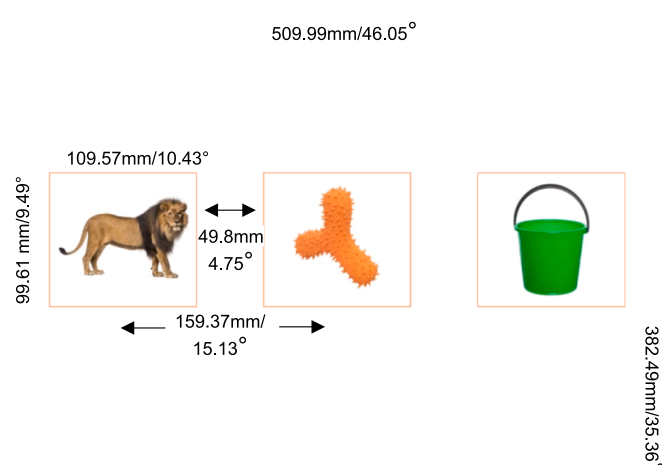

Fig. 1. Example referent selection trial with two familiar and one novel object and interest areas (not visible to participants).

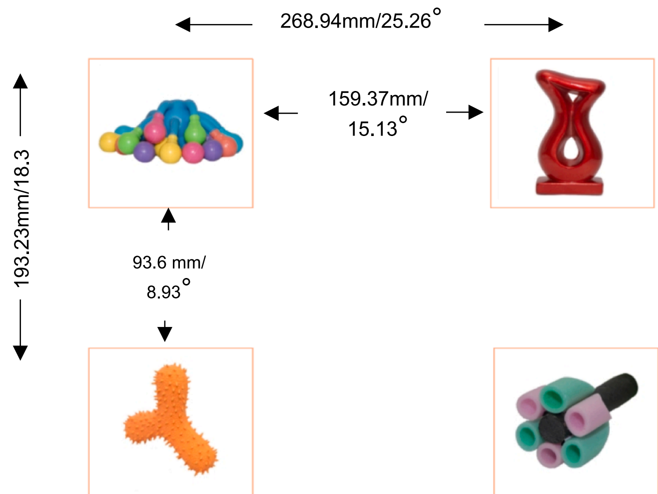

Fig. 2. Example retention trial with four novel objects (from top left to right: hux, cheem, kiv, noop) and interest areas (not visible to participants).

additional warm-up trials with familiar objects (e.g., cup, star, pig) were presented. These warm-up trials familiarised children with pointing to a computer screen (for a similar task see Halberda, 2006; Spiegel & Halberda, 2011). Before the start of each trial, an animated attention-getter appeared to direct children's attention to the centre of the screen. Objects appeared after children looked at the attention-getter for 300 ms. Children saw three familiar objects displayed horizontally across the display screen (see Fig. 1) and heard, "*Can you see the_? Point to the_. Where is the_?*" The onset of the images and audio was identical and there were no pauses between utterances. The recording played on a loop until the child pointed, after which the experimenter ended the trial. If the child did not point, the software ended the trial after 30 s (2.5 % of all trials). The experimenters provided guidance if needed, or a break if children failed to point in any of the three warm-up trials, and the task was attempted once more ($n = 6$). In previous studies, children's referent selections were measured during shorter time frames (e.g., Halberda, 2006; Mather & Plunkett, 2009; Mather & Plunkett, 2012). However, these studies presented only one competitor per trial and we presented two competitors. Additionally, allowing a longer time frame was aimed at determining how long children take to make a selection in familiar and novel target trials. We presented one target and two competitors in each trial to remain comparable to previous object-based and eye tracking-based referent selection studies that typically present 3 objects (e.g., Axelsson et al., 2012; Hilton & Westermann, 2017; Horst & Samuelson, 2008; Kucker et al., 2020).

Referent selection. Immediately after the eye tracking warm-up trials, the referent selection trials began. These trials were identical to the warm-up trials with two exceptions: children saw two familiar and one novel object on each trial, and the experimenters did not provide any guidance. Previous studies (e.g., Axelsson et al., 2018) revealed that children were more comfortable with the eye tracker when they sat on their caregiver's lap. Caregivers were asked to help keep their children still, and that we were interested in their child's independent responses, and that guidance or directing their child's attention was unnecessary. Children received two blocks of eight trials, for a total of 16 trials. Across trials, children were asked to point to eight familiar target objects once and four novel target objects twice (one in each block, for a total of eight novel target trials). Presenting familiar target trials was aimed at ensuring that children were listening to the instructions and not merely choosing the most novel object present (see Holland et al., 2018; Horst et al., 2011; Mather & Plunkett, 2009). Four novel objects were presented because children this age struggle to retain words beyond four in this kind of task (e.g., Axelsson et al., 2012; Bion et al., 2013; Horst & Samuelson, 2008). The novel targets were presented in the same order in Block 1 and Block 2 to allow even time spacing across novel objects and to avoid the same novel target appearing on consecutive trials. Presenting the novel targets across two blocks enabled us to assess how children's fixations and looking times changed across blocks as the novel targets became more familiar. Different familiar competitors were presented on each novel target trial to maintain children's attention in the task. This also increases variability and makes the task less predictable (see Twomey et al., 2018 for a review on the usefulness of variability in word learning). Whether children were asked to point to a familiar or novel target alternated across trials, which also ensured that two novel target trials did not occur sequentially. Target object locations (i.e., left, middle, right) and novel target order (i.e., first, second, third, fourth) were counterbalanced across children using four different presentation orders.

For half of the children, each referent selection trial was followed immediately by ostensive naming of the target. The target object moved up the screen, bounced four times, and the object's name was repeated once, e.g., "*Can you see the noop?*" For children in the non-ostensive naming group, there was no naming or movement.

For pointing accuracy, two experimenters stood behind the child and recorded independently where the the child was pointing. A camera, positioned behind the display monitor also recorded the child's pointing, providing a frontal view, and was consulted for trials where the two experimenters disagreed.

Immediate novel word retention. Immediately after the referent selection trials, one new familiar target trial (sock) was presented to familiarise children to the new stimuli layout with four objects per trial (one object in each quadrant; see Fig. 2). Children were then presented with the four novel word retention test trials. Presenting four objects in each trial ensured that children saw each possible novel target on each trial and an equal number of times. Object locations changed in each trial. The same audio and novel word-order was used as in the referent selection trials, but no feedback was provided in either condition. Participants received a gift voucher (10AUD) and a book before leaving.

Medium- and long-delayed novel word retention. To test how children's looking behaviours related to their longer-term retention of novel words, children were re-tested later the same day (medium delay) and the following morning (long delay). These tests took place in children's homes using an iPad (4th generation) with a 9.7″ screen, programmed using Xcode 6. The average size of the objects was 51 mm × 52 mm (10.82 × 11.03° at ~ 27 cm distance). Conducting the later tests in children's homes was aimed at reducing participant attrition.

An experimenter sat next to the child in a quiet room and held the iPad in front of the child in easy reach. To familiarise children with the touch-screen task, children first saw four warm-up trials (flower, bird, clock, boat). Before proceeding to the retention test trials, we ensured children could understand how to use the tablet. If they struggled to complete the task ($n = 17$), we restarted the familiarisation trials. Accuracy for the completed familiarisation trials was 99.31 % (i.e., one child was wrong in two trials). Four novel word retention trials followed and were presented only once. These were presented in the same order as the immediate test trials with one exception. The instructions for these trials asked children to touch the screen. (e.g., "*Can you see the noop? Touch the noop. Where is the noop?*"). Again, no guidance was provided. No ostensive naming was provided for either group. The same procedure was used for the long-delayed retention trials the next morning.

Analysis Plan

The code and anonymised data for regenerating this paper are available from https://osf.io/6yvdw/.

Referent Selection Accuracy Over the Entire Trial. First, referent selection accuracy was assessed for the familiar and novel target trials by calculating the proportion of trials where children correctly pointed to the target (of 8 for each target type). These proportions were compared to chance (0.33 due to the presence of 3 objects in each trial) using one-sample *t*-tests to confirm whether children could successfully solve disambiguation trials. We then compared pointing accuracy between the target types (familiar and novel targets), the two trial blocks (first vs. second), and the ostensive and non-ostensive groups using linear mixed effects models (LMMs).

Second, children's proportions of target looking over entire trials were calculated to determine the amount of looking to a target relative to all three objects in a given trial, target/(target + competitor 1 + competitor 2). Proportions were averaged separately for the familiar and novel target trials and were compared to chance (0.33) to assess referent selection accuracy based on looking. These proportions of target looking were also compared between the familiar and novel target trials, between the ostensive and non-ostensive groups, and across the first and second trial blocks using LMMs. Higher target proportions indicate a greater focus on the target and less on the competitors, and vice versa. Target proportions at around 33 % would indicate a fairly equal spread across a target and the competitors in a given trial and importantly, would contribute to support for a process-of-elimination explanation with children spending time fixating on competitors and not merely focusing on the novel target.

Trial durations were determined by how long it took children to point to a referent. Trial durations were therefore compared across the familiar and novel target trials, between the ostensive and non-ostensive groups, and across the first and second half of the referent selection trials using LMMs.

The LMMs were performed using jamovi 2.2.5 software and the GAMLj module 2.0.1 developed in R (Galluci, 2019) with the lme4 package (Bates et al., 2015). The aim here was to focus on the fixed effects (with fixed intercepts) as we were largely interested in the comparison between looking behaviours across familiar and novel target trials, and the interactions with the ostensive and non-ostensive groups and across trial blocks. Each analysis contained the random effect of participant (with random intercepts) which was assessed using the log-likelihood ratio test. The default convergence optimiser (bobyqa) was used to fit the models and parameters were estimated using maximum likelihood due to the focus on the fixed effects. For the initial default Type III ANOVA-style *F*-tests, the degrees of freedom were calculated using the Satterthwaite method. Categorical predictors were sum-coded (due to the inclusion of interactions) using simple contrasts, and continuous predictors were centred (see OSF https://osf.io/6yvdw/ for output files and code).

Fine-grained analyses. Cluster-based permutation analyses were performed to determine when familiar and novel target looking proportion ratios differed to chance across the first 3500 ms from noun onsets in the referent selection trials. This more detailed assessment can help determine *when* target looking proportions differ to chance and can detect effects that otherwise could be missed when looking proportions are calculated over an entire trial (see Borovsky et al., 2015). The eyetrackingR.com package (Dink & Ferguson, 2015) in R Studio 3.5.1., was used to convert the target looking samples to logit-adjusted looking time proportion ratios (log(Prop to target/(1 – Prop to target))) and these were segmented into 50 ms time bins (see also Borovsky et al., 2015). Converting the raw proportions to logit-adjusted proportion ratios allows the values to go beyond 0 and 1 which is necessary as the confidence intervals for proportions near 0 and 1 can be reduced when the values are bounded (see https://www.eyetracking-r.com/vignettes/window_analysis and Barr, 2008). As proportions of 0 or 1 cannot be log-transformed, the eyetrackingR package adds a very small value to proportions of 0, and subtracts a small value from proportions of 1 (1/2 the smallest non-zero proportion, see eyetrackingR.com). We limited the analyses to the first block to allow us to assess looking responses for the first encounter with the novel targets. This is because subsequent encounters with novel objects can differ to initial encounters (Bredemann & Vlach, 2021; Horst et al., 2011; Mather & Plunkett, 2012), and we were interested in the time course of children's focus on novel targets when they are completely novel (but see Supplementary Materials for analyses with the second trial block).

Retention Analyses. Target accuracy during the immediate, medium-, and long-delayed retention tests were assessed by calculating proportions of correct novel object selections (out of 4). These proportions were compared to chance (0.25 due to the presence of four objects in each trial) using one-sample *t*-tests to determine if children had successfully retained the words. How much target attention during referent selection predicts immediate, medium-, and long-delayed retention was also assessed and compared between the ostensive and non-ostensive groups using a LMM analysis.

Results

Referent selection accuracy over the entire trial

Referent Selection Pointing Accuracy Compared to Chance. The distribution of scores for the familiar target trials was negatively skewed as the scores were largely at ceiling. Wilcoxon's one-sample signed rank tests indicated that for the ostensive and non-ostensive groups, the proportions of trials with correct familiar target pointing was greater than chance (see Table 1). Pointing accuracy was also greater than chance for the novel target trials.

Referent Selection Pointing Accuracy Comparisons. The following variables were added as fixed effects into a linear mixed model: groups (ostensive naming, non-ostensive naming), target types (familiar, novel), trial blocks (first, second), and age and the following interactions: group-by-target type, group-by-trial block, trial block-by-target type, group-by-age, and group-by-trial block-by-target type. The random effect of participant was significant, $LRT(1) = 12.62$, $p < .001$ (random intercept variance = 0.01 $SD = 0.08$), and the intra-class correlation (ICC) was 0.19 suggesting small-to-moderate variability across participants. All the fixed effects and interactions were non-significant aside from target type, $F(1,216) = 161.07$, $p < .001$ (see also Table 2 for the fixed effects estimates and Fig. 3; see Table S1 in Supplementary Materials for remaining *F*-tests). Pointing accuracy was significantly greater for the familiar ($M = 0.98$, $SE = 0.02$) compared to the novel targets ($M = 0.74$, $SE = 0.02$), which is expected as the familiar targets were chosen to be words already known by children before the study and

Table 1
Referent selection pointing accuracy and target proportion looking times compared to chance.

	M	SD	Comparison to chance (0.33)
Referent selection pointing accuracy			
Familiar targets			
Ostensive naming	0.99	0.04	**Mdn = 1.00; Wilcoxon z = 666.00, p < .001; r_{rb} = 1.00**
Non-ostensive naming	0.97	0.07	**Mdn = 1.00; Wilcoxon z = 666.00, p < .001; r_{rb} = 1.00**
Novel targets			
Ostensive naming	0.78	0.2	**t(35) = 13.54, p < .001, d = 2.26**
Non-ostensive naming	0.7	0.2	**t(35) = 11.20, p < .001, d = 1.87**
Referent selection proportions of target looking			
Familiar targets			
Ostensive naming	0.59	0.07	**t(35) = 20.68, p < .001, d = 3.45**
Non-ostensive naming	0.5	0.07	**t(35) = 13.61, p < .001, d = 2.27**
Novel targets			
Ostensive naming	0.4	0.09	**t(35) = 4.64, p < .001, d = 0.77**
Non-ostensive naming	0.4	0.09	**t(35) = 4.43, p < .001, d = 0.74**

Table 2
Referent selection pointing accuracy and group, trial block, and target type comparison.

Names	Effect	Estimate	SE	95 % Confidence Interval		df	t	p
				Lower	Upper			
(Intercept)	(Intercept)	0.86	0.01	0.83	0.89	72.00	59.80	<.001
Group	Ostensive – Non-ostensive	0.03	0.03	−0.03	0.09	72.00	1.09	.278
Target Type	**Novel − Familiar**	**−0.24**	**0.02**	**−0.27**	**−0.20**	**216.00**	**−12.69**	**<.001**
Trial Block	Second − First	−0.04	0.02	−0.07	0.00	216.00	−1.95	.053
Child Age	Child Age	0.01	0.01	−0.01	0.03	72.00	0.94	.348
Group * Target Type	Ost – Non-ost * Novel − Familiar	0.06	0.04	−0.01	0.13	216.00	1.57	.117
Group * Trial Block	Ost – Non-ost * Second − First	0.02	0.04	−0.06	0.09	216.00	0.46	.644
Trial Block * Target Type	Second − First * Novel − Familiar	−0.07	0.04	−0.15	0.00	216.00	−1.95	.053
Group * Child Age	Ost – Non-ost * Child Age	−0.01	0.02	−0.05	0.04	72.00	−0.35	.724
Group * Trial Block * Target Type	Ost – Non-ost * Second − First * Novel − Familiar	0.15	0.07	−0.00	0.29	216.00	1.95	.053

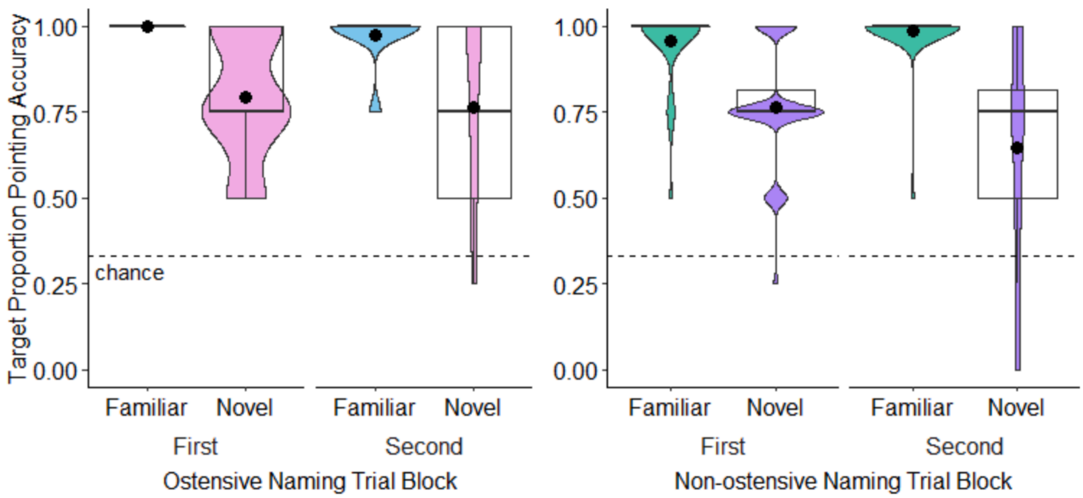

Fig. 3. Proportions of accurate target pointing in the familiar and novel target referent selection trials for the ostensive and non-ostensive groups across trial blocks note. Dashed line = chance (0.33).

the novel targets were used to ensure children did not know them at the start of the study.

Referent Selection Proportions of Target Looking Compared to Chance. For both the ostensive and non-ostensive groups, children's proportions of target looking in the novel and familiar target trials were significantly greater than chance (0.33, see Table 1). Therefore, both pointing accuracy and looking proportions to the targets indicated that the children could successfully solve disambiguation trials. The relationship between pointing accuracy and target looking time proportions was also assessed. Spearman's correlations were used for the familiar target trials due to the negatively skewed pointing scores. For the familiar target trials, the relationship was non-significant for both the ostensive $\rho(30) = 0.23$, $p = .178$, and the non-ostensive group $\rho(30) = .13$, $p = .448$. For the novel target trials, there was a significant positive correlation between pointing and target looking time proportions for both the ostensive $r(30) = .69$, $p < .001$, and the non-ostensive group $r(30) = .46$, $p = .004$. Thus, for novel target trials, proportions of target looking related to their accuracy as indicated by proportions of pointing accuracy. For the familiar target trials, children were at ceiling for pointing accuracy, which could explain the weaker relationship with looking proportions.

Referent Selection Proportions of Target Looking Comparisons. A linear mixed model analysis was performed comparing the groups (ostensive naming, non-ostensive naming), target types (familiar, novel), and trial blocks (first, second) along with age, and the following interactions: group-by-target type, group-by-trial block, group-by-age, trial block-by-target type, and group-by-trial block by target type (see Table 3 for fixed effects parameter estimates). The random effect of

Table 3
Referent selection target looking time proportions and group, trial block, and target type comparison.

Names	Effect	Estimate	SE	95 % Confidence Interval		df	t	p
				Lower	Upper			
(Intercept)	(Intercept)	0.47	0.01	0.46	0.49	71.98	59.87	<.001
Group	**Ostensive – Non-ostensive**	**0.04**	**0.02**	**0.01**	**0.07**	**71.98**	**2.80**	**.007**
Target Type	**Novel – Familiar**	**−0.15**	**0.01**	**−0.17**	**−0.12**	**215.41**	**−11.04**	**<.001**
Trial Block	**Second – First**	**−0.05**	**0.01**	**−0.07**	**−0.02**	**215.41**	**−3.70**	**<.001**
Child Age	Child Age	0.00	0.01	−0.01	0.02	73.39	0.41	.680
Group * Target Type	**Ost – Non-ost * Novel – Familiar**	**−0.08**	**0.03**	**−0.14**	**−0.03**	**215.41**	**−3.22**	**.001**
Group * Trial Block	Ost – Non-ost * Second – First	0.03	0.03	−0.02	0.08	215.41	1.21	.226
Target Type * Trial Block	**Novel – Familiar * Second – First**	**−0.06**	**0.03**	**−0.11**	**−0.01**	**215.41**	**−2.35**	**.020**
Group * Child Age	Ost – Non-ost * Child Age	−0.01	0.01	−0.04	0.02	73.39	−0.78	.440
Group * Target Type * Trial Block	**Ost – Non-ost * Novel − Familiar * Second –First**	**−0.12**	**0.05**	**−0.22**	**−0.02**	**215.41**	**−2.29**	**.023**

participant was non-significant, $LRT(1) = 0.65$, $p = .421$ (random intercept variance = 0.001 $SD = 0.023$), and the intra-class correlation (ICC) was 0.04 suggesting minimal variability across participants. There was a main effect of group, $F(1,71.98) = 7.82$, $p = .007$, with significantly greater target looking time proportions in the ostensive ($M = 0.49$, $SE = 0.01$) compared to the non-ostensive group ($M = 0.45$, $SE = 0.01$). There was a main effect of target type, $F(1,215.41) = 121.80$, $p < .001$, with greater target looking proportions in the familiar target trials ($M = 0.54$, $SE = 0.01$) compared to the novel target trials ($M = 0.40$, $SE = 0.01$). There was a main effect of trial block, $F(1,215.41) = 13.67$, $p < .001$, with significantly larger target looking proportions in the first half ($M = 0.50$, $SE = 0.01$) compared to the second half ($M = 0.45$, $SE = 0.01$). The main effect of age was non-significant, $F(1,73.39) = 0.17$, $p = .680$, as was the group-by-age interaction, $F(1,73.39) = 0.60$, $p = .440$. There were significant interactions between group and target type, $F(1,215.41) = 10.35$, $p = .001$, trial block and target type, $F(1,215.41) = 5.52$, $p = .020$, as well as group, trial block, and target type, $F(1,215.41) = 5.26$, $p = .023$, but the group-by-trial block interaction was non-significant, $F(1,215.41) = 1.47$, $p = .226$. Post-hoc Bonferroni-corrected comparisons, revealed that these results are explained by greater novel target looking proportions in the first trial block compared to the second block for only the ostensive group ($p = .014$), but not the non-ostensive group ($p = .458$). This suggests that ostensive naming led to less focus on the novel targets before pointing by the second trial block. For the familiar target trials, familiar target looking did not differ across trial blocks for the ostensive naming group ($p = .999$), and the non-ostensive group ($p = .479$) suggesting it remained high across trial blocks. The difference between groups for familiar target looking was non-significant in the first trial block ($p = .999$), but in the second trial block, the ostensive naming group's familiar target looking was significantly greater than the non-ostensive group's ($p < .001$, see Fig. 4). The difference between groups was non-significant for the novel targets for both trial blocks ($ps = .999$). This suggests that ostensive naming led to greater focus on targets for familiar targets.

In sum, compared to familiar target looking proportions, the novel target looking proportions were lower indicating greater looking times to the competitors and contributes to the suggestion that children were completing a process-of-elimination. Compared to the first block of novel target trials, by the second block, the focus became more evenly spread across the three objects for the ostensive group and there was less focus on novel targets before the selection (see Fig. 4). Interestingly, we also found for the novel target trials in the first block, this corresponds to an average of 6 fixations to the target and an average of 4 fixations to the competitors, but by the second half, children fixated 4 times to the targets and 4 times to the competitors. For the familiar target trials, children fixated around 4 times to the target and twice to the competitors in both blocks. Therefore, there were double the amount of fixations to the competitors in novel target trials relative to familiar target trials.

Referent Selection Trial Durations. Differences in referent selection trial durations were also compared between groups (ostensive naming, non-ostensive naming), between target types (familiar, novel), and across trial blocks (first, second) using a linear mixed model analysis along with the addition of age and age-by-group (see Table 4). Trial durations were positively skewed and were log-transformed which improved the distribution, but original descriptive statistics are presented here and shown in Fig. 5 for ease of interpretation. The random effect of participant was significant, $LRT(1) = 81.97$, $p < .001$ (random intercept variance = 0.01 $SD = 0.12$), and the ICC was 0.50 suggesting moderate variability across participants. The main effect of group was non-significant, $F(1,72) = 2.86$, $p = .095$ (ostensive: $M = 6263.32$ ms, $SE = 341.76$; non-ostensive: $M = 5411.59$ ms, $SE = 370.15$), but there was a main effect of target type, $F(1,214.60) = 119.95$, $p < .001$, with significantly longer trial durations for the novel target trials ($M = 7175.15$, $SE = 280.12$) compared to the familiar target trials ($M = 4499.76$, $SE = 279.77$). Trial durations were overall significantly longer in the first trial block ($M = 6323.62$, $SE = 279.77$) than in the second block ($M = 5351.28$, $SE = 280.12$), $F(1,214.60) = 15.84$, $p < .001$. The main effect of age was significant, $F(1,72.64) = 5.72$, $p = .019$, but the group-by-age interaction was non-significant, $F(1,72.64) = 0.18$, $p = .669$. The relationship with age was negative (see Table 4), suggesting that trials were shorter with increasing child age, but this relationship did not differ between the ostensive and non-ostensive groups. There were significant interactions between group and target type $F(1,214.60) = 6.57$, $p = .011$, group and trial block $F(1,214.60) = 6.16$, $p = .014$, trial block and target type $F(1,214.60) = 51.40$, $p < .001$, and group, trial block, and target type $F(1,214.60) = 9.91$, $p = .002$ (see also Table 4). Bonferroni-corrected comparisons revealed that these interactions are explained by children in both groups taking longer in the novel target trials than the familiar target trials in the first trial block (ostensive: $p < .001$; non-ostensive $p < .001$). However, in the second trial block, the difference in trial durations between the novel and familiar target trials was non-significant for the ostensive naming group ($p = .999$), but for the non-ostensive group, children were still taking longer for the novel target than the familiar target trials ($p < .001$, see Fig. 5). Therefore, ostensive naming likely helped children find the novel targets when they encountered them again. Across trial blocks, differences in trial durations were non-significant for the non-ostensive group for the familiar and novel target trials ($ps > .05$). For the ostensive

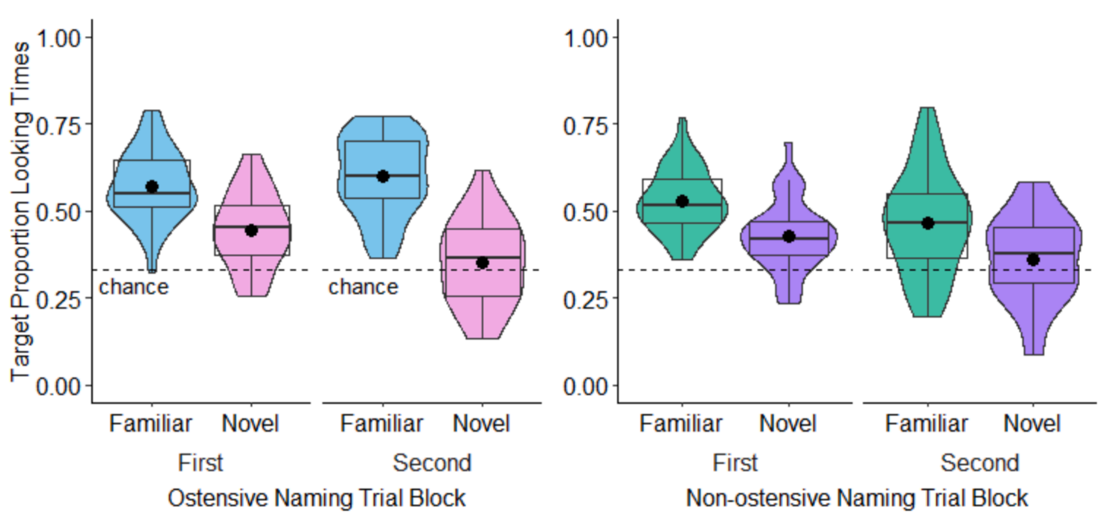

Fig. 4. Referent selection proportions of target looking times in the familiar and novel target trials for the ostensive and non-ostensive groups across trial blocks note. Dashed line = chance (0.33).

Table 4
Referent selection trial durations group, trial block, and target type comparison.

				95 % Confidence Interval				
Names	Effect	Estimate	SE	Lower	Upper	df	t	p
(Intercept)	(Intercept)	3.71	0.02	3.68	3.75	72.00	215.11	<.001
Group	Ostensive – Non-ostensive	0.06	0.03	−0.01	0.12	72.00	1.64	.104
Target Type	**Novel – Familiar**	**0.19**	**0.01**	**0.16**	**0.22**	**214.44**	**13.54**	**<.001**
Trial Block	**Second – First**	**−0.05**	**0.01**	**−0.08**	**−0.02**	**214.44**	**−3.72**	**<.001**
Child Age	**Child Age**	**−0.03**	**0.01**	**−0.06**	**−0.00**	**72.48**	**−2.29**	**.025**
Group * Target Type	**Ost – Non-ost * Novel – Familiar**	**−0.10**	**0.03**	**−0.15**	**−0.04**	**214.44**	**−3.54**	**<.001**
Group * Trial Block	**Ost – Non-ost * Second – First**	**−0.08**	**0.03**	**−0.14**	**−0.03**	**214.44**	**−2.99**	**.003**
Trial Block * Target Type	**Second – First * Novel – Familiar**	**−0.22**	**0.03**	**−0.28**	**−0.17**	**214.44**	**−7.99**	**<.001**
Group * Child Age	Ost – Non-ost * Child Age	0.01	0.03	−0.04	0.07	72.48	0.42	.673
Group * Trial Block * Target Type	**Ost – Non-ost * Second – First * Novel – Familiar**	**−0.21**	**0.06**	**−0.32**	**−0.10**	**214.44**	**−3.73**	**<.001**

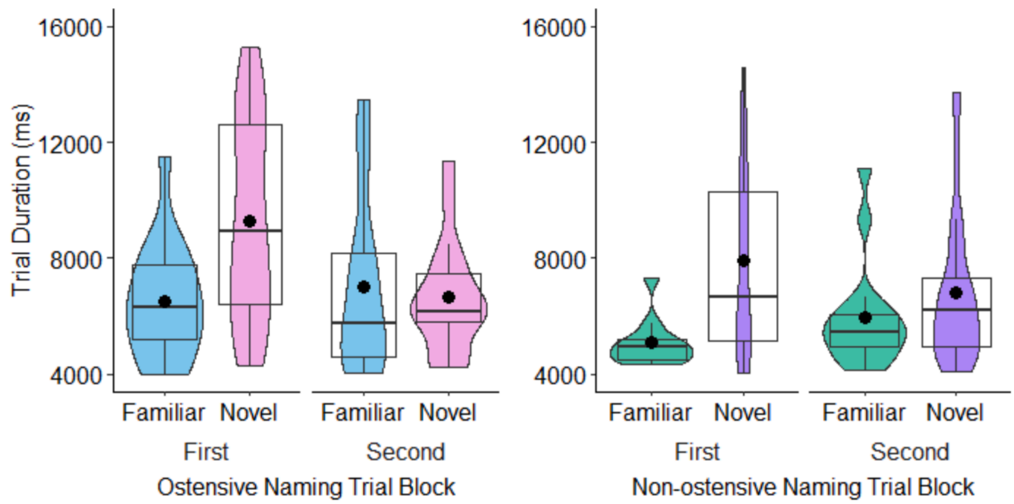

Fig. 5. Referent selection trial durations (ms) for the familiar and novel targets for the ostensive and non-ostensive groups across trial blocks.

group, they were significantly faster for the novel target trials by the second trial compared to the first ($p < .001$), but trial durations did not differ for the familiar targets ($p = .389$). Finally, the difference in trial duration between groups for familiar target trials and novel target trials was significant in both trial blocks (*ps* > .05).

Referent selection fine-grained analyses

To more closely investigate children's looking behaviours during referent selection, the time course of the target looking proportion ratios during referent selection was assessed and compared to chance every 50 ms (see Borovsky et al., 2015). Data Viewer was used to extract children's looking samples to the familiar and novel targets during referent selection from 367 ms after the target noun onsets to 3500 ms after the noun onsets. The choice to start the time window at 367 ms after noun onset is because young children take around 200 ms to initiate an eye movement after the onset of an image; and fixations prior to 367 ms are less likely to be based on auditory prompts (see Canfield et al., 1997; Swingley, 2009; Swingley & Aslin, 2000). The mean noun onset time for the target words was 861.38 ms (*SD* = 99.54 ms). Therefore, the start of the analyses corresponds to 1228.38 ms after the trial start. Previous investigations assessing fine-grained looking ratios tend to limit the time windows to 2000 ms after the time window start (e.g., Borovsky et al., 2015; Swingley, 2009; Swingley & Aslin, 2000), as longer time windows involve more variable, less meaningful looking (Canfield et al., 1997; Fernald et al., 2006). However, most of these studies typically presented two objects. As children in the current study chose between three objects and needed to point to the targets, the time window was extended to 3500 ms.

To compare the logit-adjusted proportional looking ratios to a chance ratio score (−0.301) across the time window, the eyetrackingR package was used to conduct paired *t*-tests at each 50 ms time bin to find any clusters of time bins with *t*-scores greater than 2 (as *t*-values greater than 2 are significant at the .05 alpha level with this sample size, see https://www.eyetracking-r.com/vignettes/divergence). Chance was calculated based on the presence of 3 objects, the logit-adjusted proportional looking time ratio at chance level (log(0.3333/(1-.3333))). To allow for multiple tests, a cluster-based permutation analysis was performed, which involved summing clusters of adjacent *t*-scores that are greater than 2, and comparing them to a null hypothesis distribution of cluster *t*-scores, by randomly permuting the clusters 2000 times. This cluster-based permutations approach corrects for multiple comparisons by limiting the family-wise error rate (see also Barr et al., 2014; Borovsky et al., 2015).

Ostensive group's familiar target looking compared to chance. For the familiar targets, logit-adjusted proportion ratios (log(Prop. to target/(1 – Prop, to target))) were associated with a cluster of *t*-scores greater than 2 between 500 and 1600 ms, and between 1700 and 1850 ms. Following 2000 permutations of the summed *t*-scores, the cluster between 500 and 1600 ms was revealed as significantly greater than the chance ratio score (−0.301), $t = 87.67$, $p < .001$, but the cluster between 1700 and 1850 ms was non-significant, $t = 7.02$, $p = .310$ (see vertical dashed lines in Fig. 6). Therefore, children looked at the familiar targets at greater than chance levels from 867 ms (367 + 500 ms) after the noun onset. Given the mean noun onset was 861.38 ms; (*SD* = 99.54 ms), this suggests that toddlers looked significantly more at the familiar targets from around 1728.38 ms from the presentation of the images.

Ostensive group's novel target looking compared to chance. For the novel targets, paired *t*-tests performed at each time bin revealed that clusters of *t*-scores were less than 2 between 0 and 500 ms; between 600

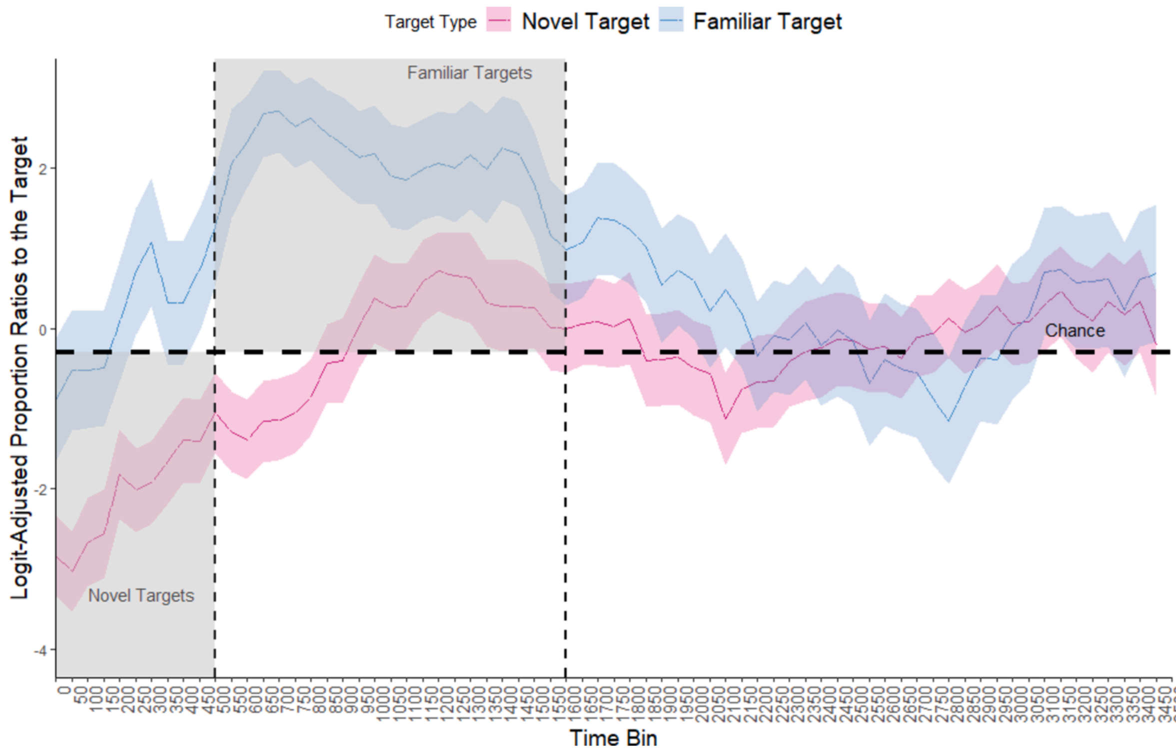

Fig. 6. Ostensive Group's Referent Selection Target Looking Proportion Ratios to the Novel and Familiar Targets in 50 ms Time Bins and Comparisons to Chance Note. 0 ms corresponds to 367 ms from noun onset; horizontal dashed line = chance level target proportion ratio (−0.301); grey shaded area below chance = novel target cluster significantly less than chance; grey shaded area above chance and vertical dashed lines = familiar target cluster significantly greater than chance.

and 650 ms, and greater than 2 between 1200 and 1250 ms. These *t*-scores were summed and following 2000 permutations of the time bins, the cluster between 0 ms and 500 ms was revealed to be significantly less than the chance ratio score (−0.301), t = -34.73, p = .017 (see grey shaded area in Fig. 6). The remaining clusters were non-significantly different to chance (between 600 and 650 ms, t = -2.20, p = .515; between 1200 and 1250, t = 2.05, p = .594). Therefore, children focussed significantly less on the novel targets relative to chance between 367 ms (367 + 0 ms) and 867 ms from noun onset. Given the mean noun onset was 861.38 ms; (*SD* = 99.54 ms), this suggests that toddlers looked significantly less at the novel target from around 1228.38 ms from the presentation of the images.

Non-ostensive group's familiar target looking compared to chance. The non-ostensive group's logit-adjusted proportion ratios to the familiar targets were associated with a cluster of *t*-scores greater than 2 between 1050 and 1450 ms and between 1500 and 2350 ms. Following 2000 permutations of the summed *t*-scores, both clusters were revealed as significantly greater than the chance ratio score (between 1050 and 1450, t = 50.69, p = .035; between 1500 and 2350, t = 93.54, p = .020, see vertical dashed and dot-dashed lines in Fig. 7). Therefore, children looked at the familiar targets at greater than chance levels from 1417 ms (367 + 1050 ms) after the noun onset. Given the mean noun onset was 861.38 ms; (*SD* = 99.54 ms), this suggests that toddlers looked significantly more at the familiar targets from around 1911 ms from the presentation of the images.

Non-ostensive group's novel target looking compared to chance. For the novel targets, logit-adjusted proportion ratios were associated with clusters of *t*-scores less than 2 between 0 and 1500 ms, and greater than 2 between 1900 and 2350 ms. Following 2000 permutations of the summed *t*-scores, the cluster between 0 and 1500 ms was revealed as significantly less than the chance ratio score (−0.301), t = -157.88, $p <$ .001, and the cluster between 1900 and 2350 was non-significant, t = 22.74, p = .071 (see grey shaded area in Fig. 7). Therefore, children looked at the novel targets at less than chance levels from 367 ms (367 + 0 ms) after the noun onset. Given the mean noun onset was 861.38 ms; (*SD* = 99.54 ms), this suggests that significantly less looking at the novel targets occurs from 1228.38 ms after trial start.

Therefore, for both the ostensive and non-ostensive groups, children looked at the novel targets less than chance initially and then proportional looking times tended to be at chance. This is further evidence for children having an initial focus on competitors and then dividing their focus across both the target and the competitors (i.e., engaging in process-of-elimination). In contrast, for the familiar target trials, there is a clear focus on the targets relative to competitors.

Retention analyses

Immediate and Delayed Retention Compared to Chance: Target Selection Accuracy. For immediate and medium-delayed retention, both the ostensive and the non-ostensive group's accuracy scores were significantly greater than chance (.25), but by the long-delayed test, only the ostensive group's accuracy was greater than chance (see Table 5).

Immediate Retention Compared to Chance: Target Looking Time Proportions. The ostensive group's target looking proportions were at chance, and the non-ostensive group's looking proportions were significantly less than chance (0.25, see Table 5).

Proportions of Novel Target Looking During Referent Selection as a Predictor of Immediate and Delayed Retention. The aim of our next analysis was to determine how much children's focus on the novel targets during referent selection was associated with immediate and delayed retention. The following variables were added as fixed effects to a linear mixed model: novel target looking proportions during referent selection, group (ostensive naming, non-ostensive naming), retention phase (immediate, medium-delayed, long-delayed, coded as a polynomial variable), age, and the following interactions: group-by-retention phase, retention phase-by-novel target looking, group-by-novel target looking, group-by-age, group-by-retention phase-by-novel

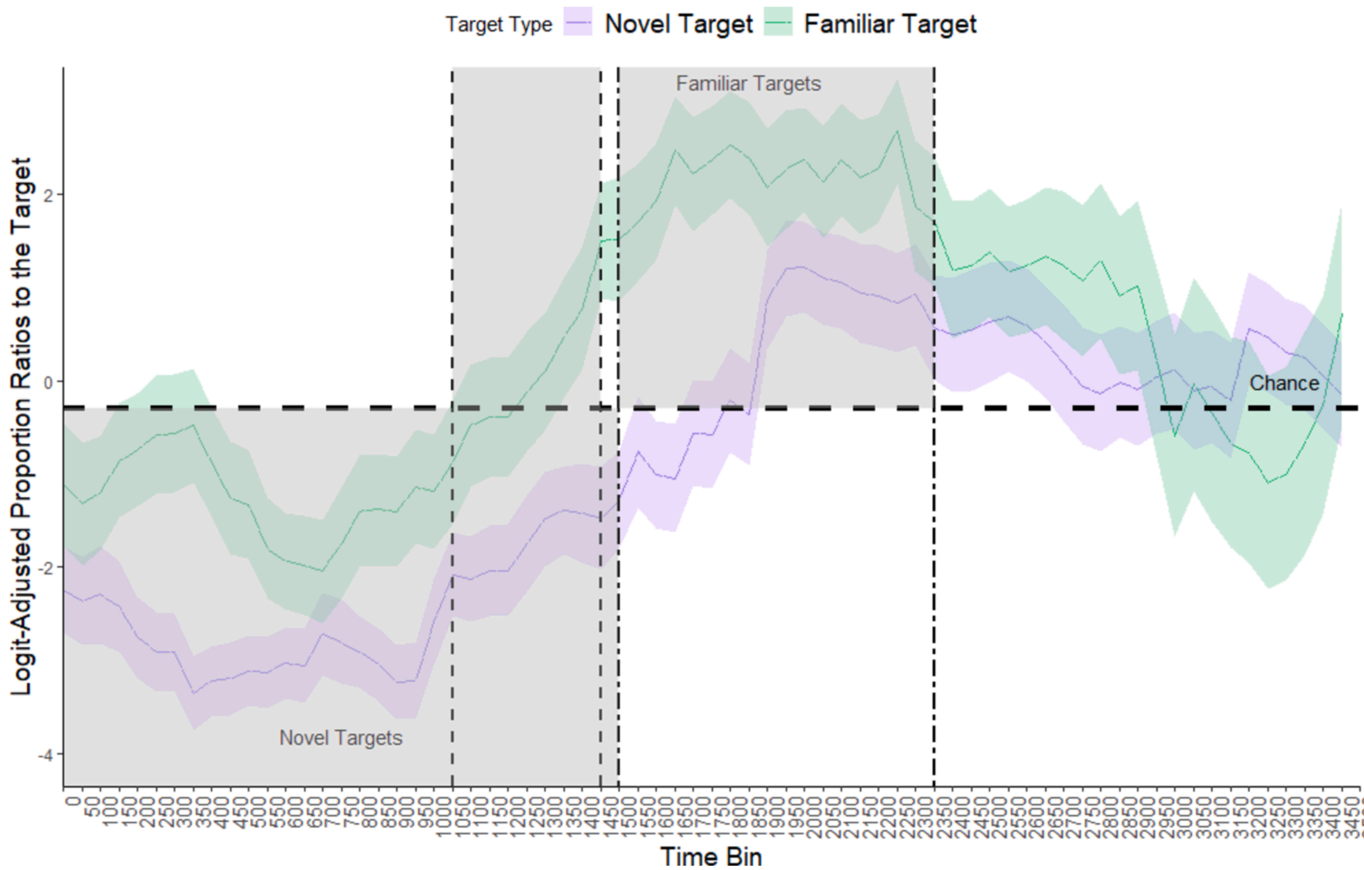

Fig. 7. Non-Ostensive Group's referent selection target looking proportion ratios to the novel and familiar targets in 50 ms time bins and comparisons to chance Note. 0 ms corresponds to 367 ms from noun onset; horizontal dashed line = chance level target proportion ratio (−0.301); grey shaded area below chance = target clusters significantly less than chance; grey shaded area above chance and vertical dashed and dot-dashed lines = familiar target clusters significantly greater than chance.

Table 5
Retention target selection accuracy and target proportion looking times and compared to chance.

	M	SD	Comparison to chance (0.25)
Immediate retention target pointing accuracy			
Ostensive naming	0.41	0.29	**t(35) = 3.26, p = .002, d = 0.54**
Non-ostensive naming	0.48	0.31	**t(33) = 4.36, p < .001, d = 0.75**
Immediate retention proportions of target looking			
Ostensive naming	0.25	0.10	t(35) = 0.27, p = .792, d = 0.04
Non-ostensive naming	0.22	0.09	**t(35) = -2.17, p = .037, d = -0.36**
Medium delay retention target selection accuracy			
Ostensive naming	0.51	0.27	**t(35) = 5.93, p < .001, d = 0.99**
Non-ostensive naming	0.40	0.27	**t(32) = 3.26, p = .003, d = 0.57**
Long delay retention target selection accuracy			
Ostensive naming	0.55	0.30	**t(35) = 5.90, p < .001, d = 0.98**
Non-ostensive naming	0.32	0.29	t(32) = 1.45, p = .157, d = 0.25

target looking (see Table 6 for the fixed effects parameter estimates). The dependent variable was pointing accuracy for immediate retention and touch accuracy at the medium- and long-delayed tests. Participant was included as a random effect and was significant, $LRT(1) = 19.65$, $p < .001$ (random intercept variance = 0.02 $SD = 0.16$). The ICC was 0.33 suggesting a small-to-moderate amount of variability across participants. The main effects of group, $F(1,67.87) = 2.94$, $p = .091$, and retention phase, $F(2,137.35) = 0.14$, $p = .871$ were non-significant, but there was a significant interaction between retention phase and group, $F(2,137.35) = 7.91$, $p < .001$. This was due to a significant difference between the groups in the linear relationship across the retention phases (β = 0.21, $p < .001$, see Table 6), which is explained by the ostensive group's retention *increasing* from immediate to long-delayed testing, and the non-ostensive group's retention *decreasing* from immediate to long-delayed testing (see also Table 5). Bonferroni-corrected post-hoc analyses revealed that retention did not differ significantly between the groups for immediate, $t(169.73) = 0.96$, $p = .999$, or medium-delayed retention, $t(136.00) = -1.63$, $p = .999$, but long-delayed retention was significantly greater in the ostensive ($M = 0.54$, $SE = 0.05$) than in the non-ostensive group ($M = 0.31$, $SE = 0.05$), $t(170.62) = -3.17$, $p = .028$.

There was also a significant effect of target looking proportions, $F(1,68.32) = 5.41$, $p = .023$, with greater target looking during referent selection predicting greater retention (β = .57, p = .023). The interactions between target looking and group, $F(1,68.32) = 0.02$, $p = .896$, and between target looking and retention phase, $F(2,137.20) = 0.08$, $p = .922$, were non-significant, but there was a significant interaction between target looking proportions, retention phase, and group, $F(1,68.32) = 5.41$, $p = .023$. This is explained by a significant difference between the groups in the linear relationship between target looking and retention across the phases (β = -1.65, $p = .002$, see Table 6). For the ostensive naming group, the greater the novel target looking during referent selection, the higher the immediate retention ($p = .009$, see Figs. 8 & 9). For the non-ostensive group, greater novel target looking was associated with better long-delayed retention ($p = .032$). This suggests that for the non-ostensive group, the benefits of greater target looking proportions were apparent after around 24 h; whereas for the ostensive group the benefits of greater target looking proportions were

Table 6
Retention Accuracy and Proportions of Novel Target Looking Times During Referent Selection.

				95 % Confidence Interval				
Names	Effect	Estimate	SE	Lower	Upper	df	t	p
(Intercept)	(Intercept)	0.44	0.03	0.38	0.49	67.87	15.96	<.001
Group	Ostensive – Non-ostensive	0.09	0.05	−0.01	0.20	67.87	1.71	.091
Retention 1	linear	−0.00	0.03	−0.06	0.05	137.66	−0.08	.940
Retention 2	quadratic	−0.01	0.03	−0.07	0.04	137.04	−0.52	.604
Prop. Target Looking	**Prop. Target Looking**	**0.57**	**0.24**	**0.09**	**1.05**	**68.32**	**2.33**	**.023**
Child Age	Child Age	−0.01	0.02	−0.06	0.03	69.87	−0.52	.603
Group * Retention 1	**Ostensive – Non-ostensive * linear**	**0.21**	**0.05**	**0.11**	**0.32**	**137.66**	**3.93**	**<.001**
Group * Retention 2	Ostensive – Non-ostensive * quadratic	−0.03	0.05	−0.14	0.07	137.04	−0.58	.562
Retention 1 * Prop. Target Looking	linear * Prop. Target Looking	0.11	0.27	−0.42	0.63	137.43	0.40	.688
Retention 2 * Prop. Target Looking	quadratic * Prop. Target Looking	−0.01	0.27	−0.54	0.51	136.97	−0.04	.969
Group * Prop. Target Looking	Ost – Non-ost * Prop. Target Lkg	0.06	0.49	−0.89	1.02	68.32	0.13	.896
Group * Child Age	Ost – Non-ost * Child Age	0.04	0.04	−0.05	0.12	69.87	0.84	.405
Group * Retention 1 * Prop. Target Lkg	**Ost – Non-ost * linear * Prop. Target Lkg**	**−1.65**	**0.54**	**−2.70**	**−0.60**	**137.43**	**−3.08**	**.002**
Group * Retention 2 * Prop. Target Lkg	Ost – Non-ost * quadratic * Prop. Target Lkg	0.37	0.54	−0.68	1.42	136.97	0.69	.489

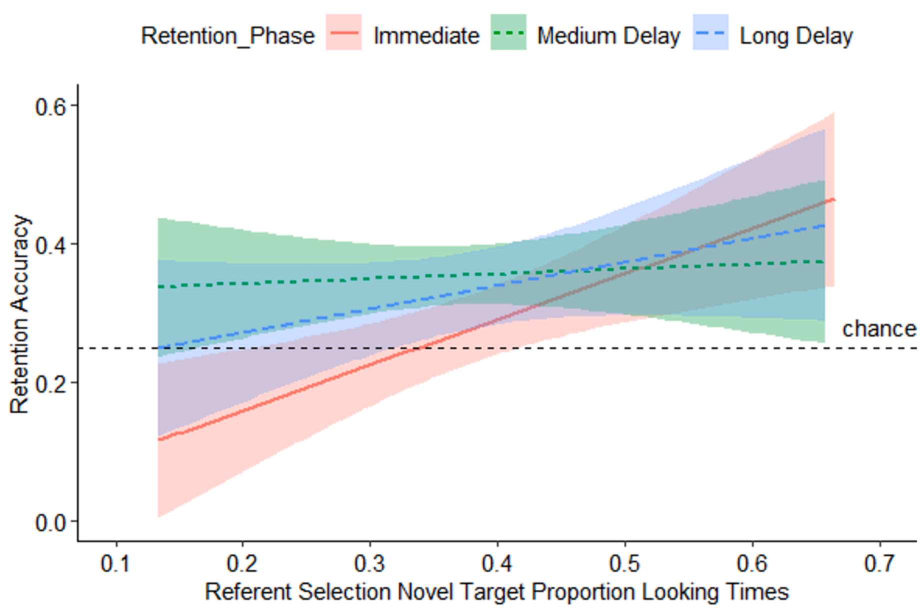

Fig. 8. Ostensive Group's proportions of novel target looking times during referent selection and immediate, medium-, and long-delayed retention accuracy note. Dashed line = chance (0.25).

apparent for immediate retention with little benefit seen in the delayed retention tests. The main effect of age, $F(1,69.87) = 0.27$, $p = .603$, and the group-by-age interaction, $F(1,69.87) = 0.70$, $p = .405$, were non-significant.

Discussion

Although learning and remembering word-object associations is a long, gradual process (e.g., Gurteen et al., 2011; McMurray et al., 2012; Storkel et al., 2017), toddlers easily solve initial disambiguation trials when they encounter novel words and objects (e.g., Merriman et al., 1995). It is unclear whether toddlers do so by using a process-of-elimination or relying on a novelty bias – or a bit of both. In the current study, toddlers were highly capable of referential disambiguation as reflected in their greater than chance pointing accuracy and looking proportions to the novel and familiar targets. According to the more fine-grained analyses, looking at the familiar targets was significantly greater than chance soon after noun onset, but target looking was significantly less than chance for the novel targets. Children also took longer to point to novel targets than familiar targets. These converging findings suggest that in novel target trials, children focus on and consider the competitors first before increasing looking towards and pointing to novel targets (for similar findings see Halberda, 2006; Hilton et al., 2019; Twomey et al., 2018). This is indicative of a process-of-elimination explanation of referent selection.

For the ostensive group, novel target looking proportions dropped from the first to the second trial block, and children took less time to point, suggesting that a single trial of referent selection of a given target supported toddlers' subsequent selection. However, the non-ostensive group still took longer to point at novel targets compared to familiar targets in the second block. Therefore, in the absence of additional feedback provided by, in this case, ostensive naming, there was less certainty compared to familiar targets in the second block when it came to pointing to novel referents.

Implications for understanding referent selection

We hypothesised that if children engage in a process-of-elimination, they should take longer to point at novel than familiar targets (see also Halberda, 2006). This was expected not only due to uncertainty when faced with a new name, but also due to time spent considering competitors. We therefore expected overall novel target looking proportions to be at chance level (33 %). In the current study, children did take longer to point and children's looking proportions to novel targets were

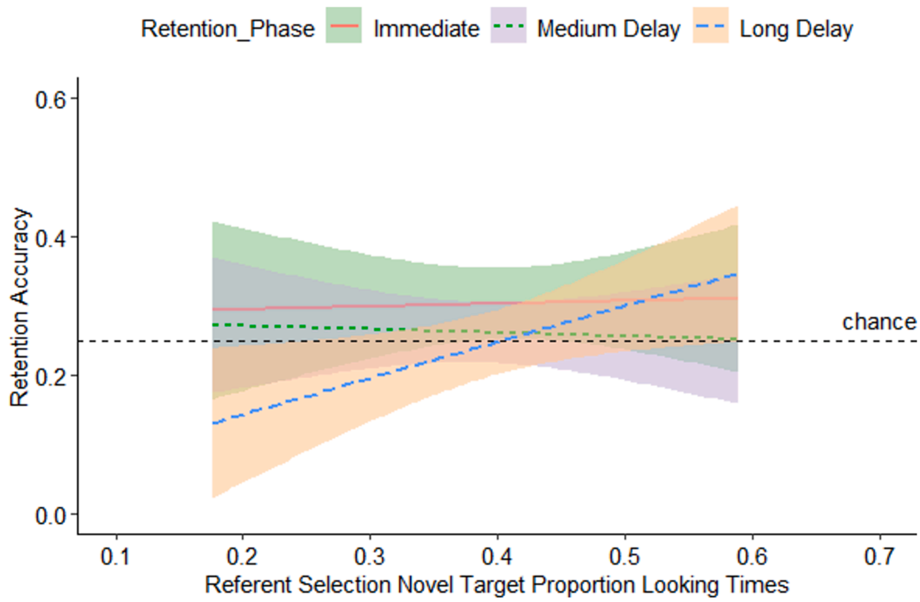

Fig. 9. Non-ostensive Group's proportions of novel target looking times during referent selection and immediate, medium-, and long-delayed retention accuracy.

at 40 % in the first trial block and closer to chance in the second block. Therefore, a focus on novelty is likely important during initial encounters, but the more fine-grained analyses indicated that children's initial focus is on familiar competitors before an increase in novel target looking. If referent selection was based primarily on a novelty bias, then children should have looked more at the novel targets relative to the familiar competitors throughout the trials. However, in the current study, children looked significantly less at novel targets for the first 1–2 s after noun onset. Therefore, we have converging evidence that disambiguation of novel targets involves a process-of-elimination. One possibility is that children looked less at the novel targets initially due to an aversion to novelty, which has been found with shy children (e.g., Hilton et al., 2019). Mather and Plunkett (2009) found that *prior* to the onset of the target word, 19- to 22-month-old children look at familiar and novel targets at chance levels. Our time course analyses, assess target looking proportions *after* the initial prompt phrase and onset of the nouns, and this is when toddlers look significantly less than chance at novel targets. This is likely due to a preference for searching familiar competitors first, in line with a process-of-elimination.

Halberda (2006) also assessed the proportion of *trials* in which 3-year-old children looked at a competitor after hearing novel words while looking at novel targets. We analysed novel target looking proportions relative to competitors, and our results align with Halberda's (2006) findings that children look at competitors before an increase in novel target looking. We also found children take longer to point to novel targets compared to familiar targets – providing further supporting evidence for a process-of-elimination. Another difference between studies is that we allowed children up to 30 s to point rather than the shorter restricted time frames of previous studies (e.g., approx. 4 sec following word onset, Halberda, 2006; Mather & Plunkett, 2012). Therefore, the looking and pointing behaviours reported here reflect the time children needed to select a referent. In familiar target trials children took an average of 4.5 s, but in novel target trials children took 7 s and engaged in double the amount of fixations to competitors.

By the second trial block, overall novel target looking proportions dropped to chance. This decline is possibly due to less need to focus on the novel target before initiating pointing, and because children were still checking competitors in these trials. This finding contrasts with Mather and Plunkett (2012) who found increasing novel target looking proportions in subsequent trials. A difference with Mather and Plunkett's (2012) study is that children were asked to find the referent a finite number of times in each trial (1–6), but in the current study children were asked multiple times as they continued to look until they pointed. The repetition in the current study likely sped up pointing in the second block (e.g., Benitez & Smith, 2012), but the novelty of the words still involved a need to check competitors before pointing. The non-ostensive group were still slower at pointing to novel than to familiar targets in the second block, indicating that ostensive naming further sped up subsequent referent selections (e.g., Benitez & Smith, 2012), and possibly also increased children's confidence in the testing context (see Axelsson et al., 2022; Hilton & Westermann, 2017).

Children have an acute awareness of and bias towards novelty from early in life (Fantz, 1964; Perone & Spencer, 2013). Mather (2013) argued that as science favours parsimony, a simple and sufficient explanation of children's referent selections is a novelty bias. Despite the differences between the methods in the current study and previous studies (e.g., Halberda, 2006; Mather & Plunkett, 2012), the evidence suggests that *both* a consideration of competitors and a bias to novelty are important for successful referent selection. This is due to children's initial focus on competitors, and their greater overall novel target looking relative to chance. The combined evidence of previous studies (Halberda, 2006; Mather & Plunkett, 2012) and the current study suggest that a reasonably simple definition of referent selection is an initial consideration of familiar competitors and an attraction to novelty.

Retention

Based on pointing and touchscreen accuracy, both the ostensive and non-ostensive groups retained the novel words at greater than chance levels immediately after referent selection and four hours later, but the following morning only the ostensive naming group's retention was greater than chance. For the non-ostensive group, retention dropped significantly from immediate testing to the following morning, whereas for the ostensive group, there was a significant increase from immediate to afternoon testing that was sustained the following morning. Therefore, there was a weakening in the strength of the word-object associations over time if children had not heard the objects ostensively named, but for those who had, their memories for the words were maintained over time.

Children's retention looking times were only measured for immediate retention. Interestingly, the children in the non-ostensive group looked significantly less to the target during immediate retention, and the ostensive group's focus on the target was at chance, but both groups pointed at the targets at greater than chance levels. These findings are perhaps a reflection of the switch from looking across 4 rather than 3 objects and all objects now being novel meaning they could no longer rely on ruling out familiar objects to support their selections. These factors likely added to the uncertainty and as the non-ostensive group received no reinforcement of the word-object associations during the referent selection phase, they likely experienced a greater level of uncertainty. Future studies should investigate the focus on targets during retention at longer time scales in relation to differing initial encoding conditions.

We hypothesised that greater novel target looking during referent selection would be associated with stronger retention, both immediately after and longer-term (e.g., Bion et al., 2013; Hilton et al., 2019; Twomey et al., 2018), particularly for the ostensive naming group (e.g., Axelsson et al., 2012). We found greater novel target looking was significantly associated with better retention for the ostensive group, but only for immediate retention. For the non-ostensive naming group, there was instead a significant relationship between novel target looking and retention the following morning. A focus on the target objects during referent selection is therefore, an important aspect of long-term acquisition of words. All children were asked to identify referents of novel words independently, but half the children were also explicitly told the novel words that referred to the novel objects to reinforce encoding of the link between the words and objects. Under these stronger encoding conditions, any benefit of greater attention to the novel targets was seen soon after, with little extra benefit later. We had speculated as to whether the supportive effect of ostensive naming would be due to the repetition of the words or due to focusing attention on novel targets. Children in the non-ostensive naming group identified the referents and arguably experienced weaker encoding conditions due to a lack of feedback on their selections, but with sufficient focus on targets during referent selection, their memories were more robust in the long term. There are few studies that investigate children's memory for novel words following referent selection over longer time scales and there have been calls for more research on this (e.g., Bredemann & Vlach, 2021). The current study provides important findings indicating that under weaker encoding conditions, helping children sufficiently focus on the word-object associations can support longer-term retention. A greater focus on the targets likely leads to better initial trace memory which has greater potential for strengthening over time such as during wakefulness and sleep (see also Henderson et al., 2021). When initial encoding conditions are strong, the current findings suggest that the word-object associations can continue to be strengthened over time.

Limitations and future directions

One limitation with the current study is that the provision of ostensive naming likely meant that there were slight differences in the timing of the progression of trials relative to the non-ostensive group. Without ostensive naming, this group proceeded across referent selection trials with shorter time gaps. We did not find any significant difference between the groups for the referent selection trial durations, but without ostensive naming, the non-ostensive group's referent selection phase was shorter leading to a faster progression to the retention phase. The time course analyses of the target looking proportions (see also Figs. 6 and 7) indicate that there are some differences between the groups. The non-ostensive group focus on the familiar targets 500 ms later than the ostensive group, but both groups focus on the novel targets at the same time, but the non-ostensive group stay significantly below chance for longer. This raises questions as to whether these slight differences are due to greater uncertainty associated with not receiving ostensive naming or due to differences in inter-trial-intervals. Future studies should equate the timing between the groups for the inter-trial-intervals with either a pause for the non-ostensive group or moving the target object up without the provision of the object's label. This will also help disentangle whether the benefit of ostensive naming is due to the greater attention to the object or the provision of the label.

Previous studies (e.g., (Kucker et al., 2018; Mather & Plunkett, 2010) found that a preference for novelty predominates before children have acquired the familiar competitors' words (e.g., 10 months of age). Children in the current study, however, were older ($M = 30$ months) and had larger vocabularies ($M = 468$ words) and the familiar competitors were chosen to be known words to children in this age range (Kalashnikova et al., 2016). A preference for novelty is likely a driving force for referent selection when there is less lexical knowledge to support children's choices and a process-of-elimination becomes more important as children acquire words. Future studies should investigate changes in looking behaviours during referent selection across age and vocabulary size such as between 10 and 30 months to determine if a novelty bias plays a larger role in referent selection at younger ages or when children have smaller vocabularies. A longitudinal approach following preverbal children could provide unique insight into the developing mechanisms underlying referent selection and later retention. Interestingly, we found that children were faster to point with increasing age, suggesting a faster ability to rule out competitors. To further assess the role of vocabulary and/or familiarity, investigating looking patterns during referent selection with novel and nameless objects with varying degrees of familiarity (e.g., Kucker et al., 2020; Mather & Plunkett, 2012) would be useful to determine if children still rely on a process of eliminating familiar objects (i.e., initial focus on more familiar novel objects) or whether it is driven by a novelty bias (i.e., a focus on the most novel object).

Future studies could also investigate the influence referent selection has on children's retention relative to other ways that words are presented to children such as explicit naming. If referent selection largely involves engaging in a process of ruling out familiar competitors (e.g., Halberda, 2006), does this limit attention to novel targets during the encoding stage? Bredemann and Vlach (2021) argued that the rapid nature of referent selection likely involves less attention to targets reducing long-term retention of word-object associations, which the current study indicates. The number of competitors present during referent selection can influence later novel word retention with one competitor better than none (Zosh et al., 2013), but too many competitors detrimental to retention (Horst et al., 2010). Therefore, at least one competitor during referent selection might provide a necessary difficulty that supports retention (Zosh et al., 2013). Comparing children's looking times to novel targets under different word learning conditions could help tease apart the role of referent selection and attention to the target on long-term retention. Future studies should also test the influence of children's attention during disambiguation on retention at even longer delays (Bredemann & Vlach, 2021), and with a varied number of novel words (Wojcik, 2021).

Finally, the findings here relate to children's word learning under controlled experimental conditions. As pointed out by Mather (2013), it would be inefficient for children to rule out every familiar object in ordinary 'real-world' environments where there is a large number of objects present. Schroer and Yu (2023) investigated children's attention with head-mounted eye trackers during exploration of objects in a home-like setting while their caregivers named objects. The degree of visual attention to the objects was not a sufficient predictor of retention, but instead it was children's manipulation of objects while attending to them that predicted retention. Investigating children's referent selections in a home-like environment with a head-mounted eye tracker could provide better ecologically valid conclusions about whether children engage in a process-of-elimination or rely on a novelty bias when there are more objects available in more scattered locations.

Conclusions

The current study comprised a mixed-method investigation of children's referent selections including pointing and eye tracking data to attempt to resolve the debate about whether children's referent selection is driven by process-of-elimination or novelty bias. Converging evidence indicated that children at this age are engaging in a process-of-elimination and likely ruling out familiar competitors before engaging in a focus on novel targets. Additional findings indicate that more focus on novel targets during referent selection was associated with better immediate retention for the ostensive naming condition, but better delayed retention for the non-ostensive group. Thus, referent selection is best described as a process-of-elimination, and a focus on novelty may supplement weaker encoding conditions such as when children do not receive feedback on their selections. Overall then, we conclude, with the current data, that at an age when children have acquired some familiar words, both an initial focus on familiar competitors prior to a focus on novelty are important to successful referent selection and a focus on novelty is important for retention following referent selection.

Author Note

Emma Axelsson https://orcid.org/0000-0002-6038-6254.

Data and additional online materials are openly available at the project's Open Science Framework page (https://osf.io/6yvdw/). We have no conflicts of interest to disclose.

Correspondence concerning this article should be addressed to Emma Axelsson, School of Psychological Sciences, University of Newcastle, Callaghan, 2308, Australia. Email: emma.axelsson@newcastle.edu.au.

CRediT authorship contribution statement

Emma L. Axelsson: Writing – review & editing, Writing – original draft, Visualization, Supervision, Project administration, Investigation, Formal analysis, Data curation, Conceptualization. **Jessica S. Horst:** Writing – review & editing, Conceptualization. **Samantha L. Playford:** Writing – review & editing, Formal analysis, Data curation. **Amanda I. Winiger:** Writing – review & editing, Formal analysis, Data curation, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jml.2024.104596.

Data availability

OSF link provided in manuscript

References

Axelsson, E., Othman, N. N., & Kansal, N. (2022). Temperament and children's accuracy and attention during word learning. *Infant Behavior and Development, 69*, Article 101771. https://doi.org/10.1016/j.infbeh.2022.101771

Axelsson, E. L., Churchley, K., & Horst, J. S. (2012). The right thing at the right time: Why ostensive naming facilitates word learning. *Frontiers in Developmental Psychology, 3*, 88. https://doi.org/10.3389/fpsyg.2012.00088

Axelsson, E. L., Dawson, R. L., Yim, S. Y., & Quddus, T. (2018). Mine, mine, mine: Self-reference and children's retention of novel words. *Front Psychol, 9*, 958. https://doi.org/10.3389/fpsyg.2018.00958

Axelsson, E. L., & Horst, J. S. (2013). Testing a word is not a test of word learning. *Acta Psychologica, 144*, 264–268. https://doi.org/10.1016/j.actpsy.2013.07.002

Axelsson, E. L., & Horst, J. S. (2014). Contextual repetition facilitates word learning via fast mapping. *Acta Psychologica, 152*, 95–99. https://doi.org/10.1016/j.actpsy.2014.08.002

Barr, D. J. (2008). Analyzing 'visual world' eyetracking data using multilevel logistic regression. *Journal of Memory and Language, 59*(4), 457–474. https://doi.org/10.1016/j.jml.2007.09.002

Barr, D. J., Jackson, L., & Phillips, I. (2014). Using a voice to put a name to a face: The psycholinguistics of proper name comprehension. *Journal of Experimental Psychology: General, 143*(1), 404–413. https://doi.org/10.1037/a0031813

Bates, D., Maechler, M., Bolker, B., & Walker, S. (2015). Fitting linear mixed-effects models using lme4. *Journal of Statistical Software, 67*(1), 1–48. https://doi.org/10.18637/jss.v067.i01

Benitez, V. L., & Smith, L. B. (2012). Predictable locations aid early object name learning. *Cognition, 125*, 339–352. https://doi.org/10.1016/j.cognition.2012.08.006

Bion, R. A. H., Borovsky, A., & Fernald, A. (2013). Fast mapping, slow learning: Disambiguation of novel word-object mappings in relation to vocabulary learning at 18, 24, and 30 months. *Cognition, 126*(1), 39–53. https://doi.org/10.1016/j.cognition.2012.08.008

Booth, A. E., McGregor, K. K., & Rohlfing, K. J. (2008). Socio-pragmatics and attention: Contributions to gesturally guided word learning in toddlers. *Language Learning and Development, 4*(3), 179–202.

Borovsky, A., Ellis, E., Evans, J. L., & Elman, J. (2015). Lexical leverage: Category knowledge boosts real-time novel word recognition in 2-year-olds. *Developmental Science, 19*(6), 918–932. https://doi.org/10.1111/desc.12343

Bredemann, C. A., & Vlach, H. (2021). Where's the advantage? Mutual exclusivity promotes children's initial mapping, but not long-term memory, for words compared to other strategies, 686554 *Frontiers in Developmental Psychology, 12*. https://doi.org/10.3389/fpsyg.2021.686554.

Canfield, R. L., Smith, E. G., Brezsnyak, M. P., Snow, K. L., Aslin, R. N., Haith, M. M., Wass, T. S., & Adler, S. A. (1997). Information processing through the first year of life: A longitudinal study using the visual expectation paradigm. *Monographs of the Society for Research in Child Development, 62*(2), i–160. https://doi.org/10.2307/1166196

Carey, S., & Bartlett, E. (1978). Acquiring a single new word. *Proceedings of the Stanford Child Language Conference*, *15*(17-29).

Clark, E. V. (1990). On the pragmatics of contrast. *Journal of Child Language, 17*(2), 417–431.

Dink, J. W., & Ferguson, B. (2015). *eyetrackingR: An R Library for Eye-tracking Data Analysis.* In http://www.eyetrackingr.com.

Fantz, R. L. (1964). Visual experience in infants: decreased attention to familiar patterns relative to novel ones. *Science*, *146*, 668-670. (NOT IN FILE).

Fernald, A., Perfors, A., & Marchman, V. A. (2006). Picking up speed in understanding: Speech processing efficiency and vocabulary growth across the 2nd year. *Developmental Psychology, 42*(1), 98–116. https://doi.org/10.1037/0012-1649.42.1.98

Fernald, A., Zangl, R., Portillo, A. L., & Marchman, V. A. (2008). Looking while listening: Using eye movements to monitor spoken language comprehension by infants and young children. In Developmental psycholinguistics: On-line methods in children's language processing. [doi:10.1075/lald.44.06fer]. John Benjamins Publishing Company.

Galluci, M. (2019). *GAMLj: General Analyses for Linear Models. [jamovi module]*. In https://gamlj.github.io/.

Gaskell, M. G., & Ellis, A. W. (2009). Word learning and lexical development across the lifespan. *Philosophical Transactions of the Royal Society B: Biological Sciences, 364* (1536), 3607–3615. https://doi.org/10.1098/rstb.2009.0213

Golinkoff, R. M., Hirsh-Pasek, K., Bailey, L. M., & Wenger, N. R. (1992). Young children and adults use lexical principles to learn new nouns. *Developmental Psychology, 28*(1), 99–108.

Grassmann, S., Schulze, C., & Tomasello, M. (2015). Children's level of word knowledge predicts their exclusion of familiar objects as referents of novel words. *Frontiers in Psychology, 6*. https://doi.org/10.3389/fpsyg.2015.01200

Gurteen, P. M., Horne, P. J., & Erjavec, M. (2011). Rapid word learning in 13- and 17-month-olds in a naturalistic two-word procedure: Looking versus reaching measures. *Journal of Experimental Child Psychology, 109*, 201–217. https://doi.org/10.1016/j.jecp.2010.12.001

Halberda, J. (2003). The development of a word-learning strategy. *Cognition, 87*(1), B23–B34.

Halberda, J. (2006). Is this a dax which I see before me? Use of the logical argument disjunctive syllogism supports word-learning in children and adults. *Cognitive Psychology, 53*(4), 310–344.

Heibeck, T. H., & Markman, E. M. (1987). Word learning in children - an examination of fast mapping. *Child Development, 58*(4), 1021–1034.

Henderson, L. M., van Rijn, E., James, E., Walker, S., Knowland, V. C. P., & Gaskell, M. G. (2021). Timing storytime to maximize children's ability to retain new vocabulary, 105207 *Journal of Experimental Child Psychology, 210*. https://doi.org/10.1016/j.jecp.2021.105207.

Hilton, M., Twomey, K. E., & Westermann, G. (2019). Taking their eye off the ball: How shyness affects children's attention during word learning. *Journal of Experimental Child Psychology, 183*, 134–145. https://doi.org/10.1016/j.jecp.2019.01.023

Hilton, M., & Westermann, G. (2017). The effect of shyness on children's formation and retention of novel word–object mappings. *Journal of Child Language, 44*(6), 1394–1412. https://doi.org/10.1017/S030500091600057X

Holland, A. K., Hyde, G., Riggs, K. J., & Simpson, A. (2018). Preschoolers fast map and retain artifact functions as efficiently as artifact names, but artifact actions are the most easily learned. *J Exp Child Psychol, 170*, 57–71. https://doi.org/10.1016/j.jecp.2017.12.013

Horst, J. S. (2011). *Slow Down: High Attentional Demands Hinder Children's Word Learning via Fast Mapping* Xth International Congress for the Study of Child Language, Montreal, Canada.

Horst, J. S., & Hout, M. C. (2016). The Novel Object and Unusual Name (NOUN) Database: A collection of novel images for use in experimental research. *Behaviour Research Methods, 48*(4), 1393–1409. https://doi.org/10.3758/s13428-015-0647-3

Horst, J. S., & Samuelson, L. K. (2008). Fast mapping but poor retention by 24-month-old infants. *Infancy, 13*(2), 128–157. https://doi.org/10.1080/15250000701795598
Horst, J. S., Samuelson, L. K., Kucker, S. C., & McMurray, B. (2011). What's new? Children prefer novelty in referent selection. *Cognition, 18*(2), 234–244.
Horst, J. S., Scott, E. J., & Pollard, J. P. (2010). The role of competition in word learning via referent selection. *Developmental Science, 13*(5), 706–713. https://doi.org/10.1111/j.1467-7687.2009.00926.x
Horst, J. S., Twomey, K. E., Morse, A. F., Nurse, R., & Cangelosi, A. (2020). When object color is a red herring: Extraneous perceptual information hinders word learning via referent selection. *IEEE Transactions on Cognitive and Developmental Systems, 12*(2), 222–231. https://doi.org/10.1109/TCDS.2019.2894507
Kalashnikova, M., Schwarz, I., & Burnham, D. (2016). OZI: Australian English communicative development inventory. *First Language, 36*(4), 407–427. https://doi.org/10.1177/0142723716648846
Kucker, S. C., McMurray, B., & Samuelson, L. K. (2018). Too much of a good thing: How novelty biases and vocabulary influence known and novel referent selection in 18-month-old children and associative learning models. *Cognitive Science, 42*(S2), 463–493. https://doi.org/10.1111/cogs.12610
Kucker, S. C., McMurray, B., & Samuelson, L. K. (2020). Sometimes it is better to know less: How known words influence referent selection and retention in 18- to 24-month-old children, 104705 *Journal of Experimental Child Psychology, 189*. https://doi.org/10.1016/j.jecp.2019.104705.
Mather, E. (2013). Bootstrapping the early lexicon: How do children use old knowledge to create new meanings? *Frontiers in Psychology, 4*, 2–3.
Mather, E., & Plunkett, K. (2009). Learning words over time: The role of stimulus repetition in mutual exclusivity. *Infancy, 14*(1), 60–76. https://doi.org/10.1080/15250000802569702
Mather, E., & Plunkett, K. (2010). Novel labels support 10-month-olds' attention to novel objects. *Journal of Experimental Child Psychology, 105*(3), 232–242. https://doi.org/10.1016/j.jecp.2009.11.004
Mather, E., & Plunkett, K. (2012). The role of novelty in early word learning. *Cognitive Science, 36*(7), 1157–1177.
McMurray, B., Horst, J. S., & Samuelson, L. K. (2012). Word learning as the interaction of online referent selection and slow associative learning. *Psychological Review, 119*(4), 831–877. https://doi.org/10.1037/a0029872
Merriman, W. E., Marazita, J., & Jarvis, L. (1995). Children's disposition to map new words onto new referents. In *Beyond names for things: Young children's acquisition of verbs.* (pp. 147-183). Lawrence Erlbaum Associates, Inc.
Mervis, C. B., & Bertrand, J. (1994). Acquisition of the novel name nameless category (N3c) principle. *Child Development, 65*(6), 1646–1662.
Perone, S., & Spencer, J. P. (2013). Autonomous visual exploration creates developmental change in familiarity and novelty seeking behaviors. *Frontiers in Psychology, 4*. https://doi.org/10.3389/fpsyg.2013.00648
Quine, W. V. O. (1960). Word and object: An inquiry into the linguistic mechanisms of objective reference. MIT Press.
Repnik, K. M., Chondrogianni, V., & Sorace, A. (2021). Linking disambiguation and retention in a developmental eye-tracking study with monolingual and multilingual children, 105072 *Journal of Experimental Child Psychology, 206*. https://doi.org/10.1016/j.jecp.2020.105072.
Schroer, S. E., & Yu, C. (2023). Looking is not enough: Multimodal attention supports the real-time learning of new words. *Developmental Science, 26*(2). https://doi.org/10.1111/desc.13290. e13290.
Spiegel, C., & Halberda, J. (2011). Rapid fast-mapping abilities in 2-year-olds. *Journal of Experimental Child Psychology, 109*, 132–140.
Storkel, H. L., Voelmle, K., Fierro, V., Flake, K., Fleming, K. K., & Romine, R. S. (2017). Interactive book reading to accelerate word learning by kindergarten children with specific language impairment: Identifying an adequate intensity and variation in treatment response. *Language, Speech, and Hearing Services in Schools, 48*(1), 16–30. https://doi.org/10.1044/2016_LSHSS-16-0014
Swingley, D. (2009). Onsets and codas in 1.5-year-olds' word recognition. *Journal of Memory and Language, 60*(2), 252–269. https://doi.org/10.1016/j.jml.2008.11.003
Swingley, D., & Aslin, R. N. (2000). Spoken word recognition and lexical representation in very young children. *Cognition, 76*(2), 147–166.
Twomey, K. E., Ma, L., & Westermann, G. (2018). All the right noises: Background variability helps early word learning. *Cognitive Science, 42*(S2), 413–438. https://doi.org/10.1111/cogs.12539
Twomey, K. E., Ranson, S. L., & Horst, J. S. (2014). That's more like it: Multiple exemplars facilitate word learning. *Infant and Child Development, 23*(2), 105–122. https://doi.org/10.1002/icd.1824
Vlach, H. A., & Sandhofer, C. M. (2012). Fast mapping across time: Memory processes support children's retention of learned words. *Frontiers in Developmental Psychology, 3*, 1–8.
Waxman, S. R., & Booth, A. E. (2000). Principles that are invoked in the acquisition of words, but not facts. *Cognition, 77*(2), B33–B43.
Wojcik, E. H. (2013). Remembering new words: Integrating early memory development into word learning. *Frontiers in Psychology, 4*, 151. https://doi.org/10.3389/fpsyg.2013.00151
Wojcik, E. H. (2021). The effect of the number of labeled objects on novel referent selection across short and long time delays. *Language Learning and Development, 17*(4), 411–424. https://doi.org/10.1080/15475441.2021.1909483
Zosh, J. M., Brinster, M., & Halberda, J. (2013). Optimal contrast: Competition between two referents improves word learning. *Applied Developmental Science, 17*(1), 20–28. https://doi.org/10.1080/10888691.2013.748420