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#### **Authors**

Mather, Emily  
Plunkett, Kim

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# Rapid word ‘mapping’ at 10 months of age

Emily Mather (emily.mather@psy.ox.ac.uk)

Department of Experimental Psychology, University of Oxford  
South Parks Road, Oxford, UK. OX1 3UD.

Kim Plunkett (kim.plunkett@psy.ox.ac.uk)

Department of Experimental Psychology, University of Oxford  
South Parks Road, Oxford, UK. OX1 3UD.

## Abstract

Where does the ‘mutual exclusivity’ bias to map novel labels onto novel objects come from? In an intermodal preferential looking task, we found that novel labels enhance 10-month-olds’ interest in a novel object over a familiar object. In contrast, familiar labels and a neutral phrase gradually reduced attention to a novel object. Markman (1989, 1990) has argued that the name for a familiar object has to be recalled to rule out the object as the referent of a novel label. Yet, at 10 months of age, infants’ attention might be guided by the *novelty* of objects and labels, rather than knowledge of the names for familiar objects. Mutual exclusivity, as a language-specific bias, might emerge from a more general constraint on attention and learning.

**Keywords:** cognitive development; language acquisition; psychology.

## Introduction

Infants can use their existing vocabulary to form new word mappings. This ability is commonly known as the ‘mutual exclusivity’ (ME) assumption: Infants will map a novel label onto a novel object, rather than a familiar object. One prominent explanation of ME is that infants reject second labels for objects which already have names (Markman, 1989, 1990)<sup>1</sup>. Other explanations include the *novel nameless category* (N3C) principle (Mervis & Bertrand, 1994) and the *principle of contrast* (Clark, 1987). All of these accounts of ME require that the infant knows the name for the familiar object. Current evidence suggests that infants use the ME assumption to guide word learning from around 15 to 17 months of age (Halberda, 2003; Markman, Wasow, & Hansen, 2003).

The computations involved in ME have yet to be identified. How does the infant judge the novelty of a label? Does the infant have to retrieve or know the name for the familiar object? One response to these questions is to investigate how stimulus properties determine the use of ME. For example, Merriman and Bowman (1989) varied both the lexical status (i.e., whether an object was name-known or name-unknown) and novelty of objects in one experiment, and found that object novelty was more

important than lexical status in guiding two-year-olds’ mapping of a novel label (see also Merriman & Schuster, 1991).

An alternative approach to understanding the cognitive processes underlying ME is to study the development of the word-learning strategy. Halberda (2003) found evidence of ME in an intermodal preferential looking (IPL) task at 17 months of age. Infants were presented with one familiar and one novel object, and heard a novel label. While 17-month-olds increased attention to the novel object upon hearing the novel label, 16-month-olds did not. In contrast, 14-month-olds increased attention to the familiar object. Based on these developmental changes, Halberda suggested that ME is implemented as the logical argument “Not A, therefore B” (the disjunctive syllogism). Fourteen-month-olds’ attention to the familiar object in response to the novel label might represent the first step in ‘ruling out’ the familiar object as the referent; however, they apparently struggled to complete this step.

If infants respond systematically to novel labels from as young as 14 months, then we might be able to observe other precursors to ME at even younger ages. One enduring question is whether ME, as a linguistic constraint, might emerge from simpler learning mechanisms? Theories of associative learning (e.g., Mackintosh, 1975; Pearce & Hall, 1980) predict the *selective* formation of new associations. For example, pre-exposure to a stimulus reduces the associability of the stimulus (a phenomenon known as ‘latent inhibition’; see Lubow, 1973, 1989). A basic learning mechanism could guide the infant towards selectively associating a novel label with a novel object.

Relatedly, some studies demonstrate that object novelty can facilitate or disrupt the ME response depending on whether the name-known or name-unknown category exemplar is the more novel (Merriman & Bowman, 1989; Merriman & Schuster, 1991). It is also well-known that from birth, infants typically prefer novel stimuli over habituated stimuli (e.g., Slater, Morison, & Rose, 1982, 1983).

Thus, even very young infants might respond systematically to familiar and novel objects upon hearing a novel label. If evidence for the use or development of the ME response can be found for infants prior to any substantial vocabulary development, this would suggest that the ME assumption starts out as a general constraint on learning.

<sup>1</sup> We use the term ‘mutual exclusivity’ in a neutral manner to refer to the *behavior* of mapping a novel label to a novel object, rather than a familiar object. Markman (e.g., 1989, 1990) has previously used the term to refer to a specific theoretical account of this behavior.

We report an IPL experiment with 10-month-olds to investigate their attention to familiar and novel objects upon hearing different kinds of labels and phrases. On each trial, infants were presented with one familiar object and one novel object. Infants heard either a familiar label, a novel label, or a ‘neutral’ directive phrase.

At 10 months of age, a linguistic constraint might not be available to produce the mutual exclusivity response. However a basic habituation or general learning mechanism could also create a mutual exclusivity response to novel labels. Therefore, we predict that 10-month-olds will attend more to a novel object upon hearing a novel label compared to hearing either a familiar label or a neutral phrase. Infants’ responses on familiar label trials and from parental vocabulary report can be used to check whether the infants know the familiar object names, facilitating interpretation of their behavior.

## Experiment 1

### Participants

Forty-two full-term 10-month-olds ( $M = 10.1$  months,  $Range = 9.7$  months to 10.5 months; 24 male and 18 female) participated. Four additional infants were excluded due to: fussiness (1), parental interference (1), refusal to look (1), and side bias (1). All infants had healthy hearing and vision, were recruited via the local maternity ward, and came from homes where only English was spoken.

### Stimuli

**Auditory Stimuli** Speech stimuli were recorded from a native female speaker of English in an infant-directed manner. Stimuli were six familiar labels (*ball, car, cup, shoe, sock, spoon*) and two novel labels (*meb, wug*) each uttered in the frame “Look!...Look at the X!...Look! X!”, and the control phrase “Look!...Look at that!...Oooh!...Look there!”. The phrase “Look!” was used as an attention stimulus.

**Visual stimuli** Visual stimuli were color images of six typical object exemplars corresponding to the six familiar labels, and six novel objects that the infants were unlikely to have encountered (e.g., accordion, hair curler, etc.). Examples are provided in Figure 1. A red cross was used as an attention stimulus.

### Design

The experiment consisted of 12 trials, each presenting a familiar and novel object. Each trial lasted 10 s, accompanied by one of three types of auditory stimulus. Familiar Label trials presented the name for the familiar object. Novel Label trials presented a novel name for the novel object. Control trials presented the phrase “Look!...Look at that!...Oooh!...Look there!”. Label onsets were at 4633 ms and 7133 ms during the trial (onsets were for ‘that’ and ‘there’ for Control trials). Allowing for a 367 ms processing latency (Swingle & Aslin, 2000), trials were

split into four 2.5 s phases: Two pre-naming and two post-naming phases (see Figure 2).



Figure 1: Example of a trial block

The 12 trials were split into two halves of six trials; a different set of objects and labels was presented in each half. Each half was further divided into two blocks of three trials, where each trial within a block presented different familiar and novel objects. The first block in each half presented one example of each trial type (see Figure 1). The second block in each half presented the same sequence of trials as the first block, counterbalancing for side of presentation. Therefore, every trial had both an original and repeat presentation. Thus, during the experiment infants heard two novel labels, two familiar labels, and the control phrase. The order of trials within a block was randomised for each infant.

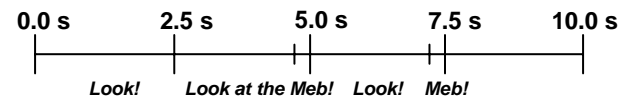


Figure 2: Trial timeline

To create the pairs of object images, two sets of six familiar and novel object pairs were randomly constructed, with the constraint that no pair was repeated across sets. Approximately half the infants were tested on one set, while the remaining infants were tested on the other set. Across infants, each pair of objects served under each of the three trial types. Each novel label was rotated across six object pairs. Within each half of the experiment, familiar and novel objects appeared equally to the left- and right-hand side of the display. Side of presentation was counterbalanced for every object pair across blocks.

### Procedure

Prior to participation, parents completed a British adaptation of the MacArthur Communicative Development Inventory (British CDI; Hamilton, Plunkett, & Schafer, 2000). During the experiment, infants sat on their caregiver’s lap facing a widescreen display (1.1 x 0.4 m) with their eyes at a distance of approximately 0.8 m, level with the vertical

midpoint of the images and at an equal horizontal distance from both images. Images were positioned at a distance of 62 cm center-to-center, each with a display size of 32 x 24 cm. Two cameras mounted directly above the horizontal midpoints of each image recorded infants' eye movements. Synchronised camera signals were routed via a digital splitter to produce two time-locked images. Auditory stimuli were delivered via two loudspeakers centrally positioned side-by-side above the display. Caregivers were asked to keep their eyes closed, to wear headphones playing music, and to not point at the screen. Trials were launched by the experimenter when the infant looked toward the screen. If the infant looked away between trials, the attention stimuli were presented to return the infant's gaze to center.

**Scoring** Digital videos were coded offline on a frame-by-frame basis (every 40 ms) by a skilled blind coder. Every fixation was coded as either left looking, right looking or other looking. Coding reliability was assessed by a second blind coder for a random sample of 15% of infants ( $N = 7$ ). The mean intraclass correlation coefficient was  $r = .984$  (range = .957 - .997).

## Results

**Main analysis** A proportion of familiar object fixation measure (total duration of fixations to the familiar object divided by total duration of fixations to both objects) was calculated for each of the four 2.5 s trial phases (see Figure 2), to observe how infants' looking behavior unfolded during the trial. This trial phase factor was entered into a preliminary repeated-measures ANOVA with the factors of experiment half, trial repetition, and trial type. There were no significant interactions or main effects for experiment half and trial repetition (all  $ps > .2$ )<sup>2</sup>; further analyses are collapsed across these factors.

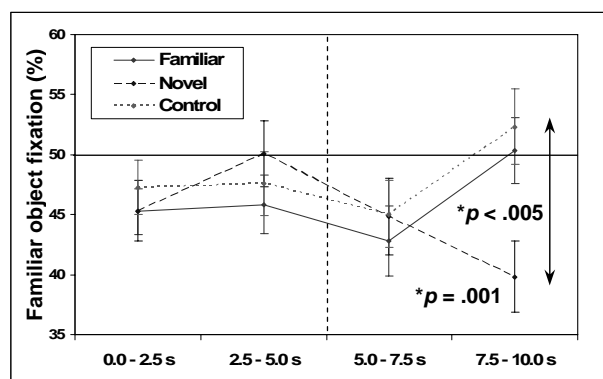


Figure 3: Proportion of familiar object fixation as a function of trial type (Error bars are +/- 1 S.E.)

<sup>2</sup> Eighteen infants contributed data to all 48 cells of the half X repeat X trial type X trial phase design. Further analysis collapsed across the experiment half factor, in which 39 of 42 infants contributed data, also did not reveal any interactions or main effects for trial repetition (all  $ps > .4$ ).

Figure 3 illustrates how attention to the familiar object unfolded as a function of trial type. During the first three trial phases, there was little difference between trial types. However, during the final trial phase, attention to the novel object was greater during novel label trials than during either familiar label or control trials. In a repeated-measures ANOVA, there was a significant interaction between trial type and trial phase,  $F(4.6, 185.4) = 2.36$ ,  $\eta_p^2 = .056$ ,  $p < .05$  (Greenhouse-Geisser corrected). There were no main effects (all  $ps > .15$ ). An analysis of simple main effects for each trial phase did not reveal significant differences between conditions for the first three trial phases (all  $ps > .5$ ), but a significant effect of condition for the fourth trial phase,  $F(2, 80) = 4.35$ ,  $\eta_p^2 = .98$ ,  $p = .016$ .

During the fourth trial phase, the proportion of familiar object fixation in the novel label condition was significantly different to both the control condition,  $t(41) = 3.02$ ,  $d = .47$ ,  $p < .005$ , and the familiar label condition,  $t(40) = 2.41$ ,  $d = .38$ ,  $p < .025$ . The familiar label and control conditions were not significantly different to each other,  $t(40) = .43$ ,  $ns$ . The proportion of attention to the familiar object in the novel label condition at 39.8% ( $SD = 19.3$ ) was significantly below chance,  $t(41) = -3.41$ ,  $d = .53$ ,  $p = .001$ , and indicates a preference to fixate the novel object. The proportion of attention to the familiar object in both the familiar label ( $M = 50.4\%$ ,  $SD = 17.4$ ) and control condition ( $M = 52.4\%$ ,  $SD = 20.3$ ) was not significantly different to chance for the fourth trial phase (all  $ps > .4$ )<sup>3</sup>.

Finally, it is worth noting that even though there were no significant differences between conditions during the two pre-naming phases (0 - 2.5 s & 2.5 - 5.0 s), there was a preference across all conditions to fixate the novel object more than the familiar object. Averaging across conditions and the first two trial phases, preference for the familiar object ( $M = 46.9\%$ ,  $SD = 7.07$ ) was significantly below chance,  $t(41) = -2.86$ ,  $p < .005$ . The relation between this 'baseline' preference for the novel object and the subsequent effect of hearing different labels and phrases is discussed below.

**CDI Analysis** Parental report indicated that the mean number of words understood by the infants was 25 words (Range = 0 - 102 words) and the mean number of words produced was 1 word (Range = 0 - 6 words). Parents reported low levels of comprehension for the six familiar object labels used in the study: Ball (29 %), Car (19 %), Cup (5 %), Shoe (7 %), Sock (10 %), and Spoon (12 %). The inclusion of a median split on infants' comprehension vocabulary as a factor in the main analysis did not reveal

<sup>3</sup> One infant did not contribute to the trial type X trial phase analysis due to missing data for the fourth trial phase of the familiar label condition. However, the exclusion of this infant resulted in a highly similar pattern of findings for the fourth trial phase: novel label vs. control condition,  $p = .007$ , and novel label to chance,  $p = .003$ .

any significant interactions with the other experimental variables. There was a main effect of vocabulary, where high vocabulary infants had a lower preference for the familiar object (i.e., greater preference for the novel object) than low vocabulary infants, 43.0 % vs. 50.0 %,  $F(1, 39) = 12.4$ ,  $p = .001$ . Finally, the exclusion of trials where infants were reported to comprehend the name of the familiar object resulted in a similar pattern of findings to those reported in the main analysis.

## Discussion

During the experiment, infants' responses to familiar and novel objects did not initially differ according to the type of labelling event. Yet, toward the end of the trial, interest in the novel object was significantly greater after hearing a novel label, than after hearing a familiar label or neutral phrase. Therefore, novel labels enhance 10-month-olds' interest in novel objects. The present findings are evidence for the mutual exclusivity response at a considerably younger age than previously thought (see Halberda, 2003; Markman, Wasow, & Hansen, 2003).

It is notable that there was no difference in looking behavior across conditions following the first presentation of a label. However, interest in the novel object differed across conditions following the second presentation of a label. It is not certain that the second presentation of the label was necessary to produce this difference; the difference between conditions might have slowly unfolded in response to the first label (see Mather & Plunkett, 2009, for the role of label repetition in ME). In either case, it was specifically a novel label which sustained interest in the novel object during the 7.5 – 10 s phase of the trial.

In previous IPL studies of ME, infants displayed a pre-naming preference for the *familiar* object (see White & Morgan, 2008). Therefore, ME has been indexed as a decrease in attention to the familiar object (i.e., an increase in attention to the novel object) between the pre- and post-naming phases of novel label trials. In contrast, we found a pre-naming preference for the novel object. Thus, for the 10-month-olds, the novel label did not serve to shift attention away from the familiar object. However, attention to the novel object persisted during novel label trials, but not during familiar label or control trials. Thus, attention to the novel object was congruous with hearing a novel label, but not with hearing either a familiar label or even a neutral phrase.

We had predicted that 10-month-olds would produce the mutual exclusivity response because either a linguistic constraint or general learning mechanism could cause this behavior. The young age of the infants, and their limited vocabulary resources, lends support to the latter explanation. However, it is important to examine the experimental evidence for whether or not infants knew the names for the familiar objects.

During familiar label trials, the infants did not look at the familiar object upon hearing it named. One explanation is

that the infants did not comprehend the familiar object names. Parental vocabulary report supports this interpretation, with very low levels of reported comprehension for all six familiar object names. However, British CDI data must be treated with some caution; a study by Houston-Price, Mather, and Sakkalou (2007) found that British parents appear to underestimate comprehension vocabulary for infants aged between 15 and 21 months. It is currently unknown whether parents underreport vocabulary for younger infants.

A related possibility is that the infants had weak representations of the familiar word mappings, but could not inhibit attention to the novel object. During familiar label trials, attention to the novel object decreased after both presentations of the familiar label. However, if the infants had difficulty recognising the familiar word mappings, then *recall* of the familiar object name during novel label trials would have proven difficult.

In summary, both the parental report and experimental data suggest that the 10-month-olds did not know the familiar word mappings. Nonetheless, we wished to understand whether 10-month-olds might evidence comprehension of the familiar words under different conditions. In Experiment 1, infants' interest in novel objects might have disrupted attention to the named familiar object. Hence, in Experiment 2 we paired familiar objects together, labelling each object across trials. The trials otherwise had the same timing of visual and auditory stimuli as Experiment 1.

## Experiment 2

### Participants

Twenty-four full-term 10-month-olds ( $M = 10.1$  months,  $Range = 9.8$  months to 10.4 months; 11 male and 13 female) participated. Six additional infants were excluded due to: fussiness (4), difficulty coding (1), and equipment failure (1). All infants had healthy hearing and vision, were recruited via the local maternity ward, and came from homes where only English was spoken.

### Stimuli

The visual and auditory stimuli were the six familiar objects and labels used in the familiar label condition of Experiment 1 (see above), with the exception of the auditory attention stimulus which was a chiming sound.

### Design

The experiment consisted of 12 trials, each presenting two familiar objects and the name for one of the two objects. Each trial lasted 10 s and label onsets were at 4633 ms and 7133 ms during the trial. Infants were tested on one of two sets of familiar object pairs. Each set was created by randomly pairing the six objects into three object pairs, with the constraint that there were different pairings in each set (*ball-spoon*, *car-sock*, *cup-shoe*, or *ball-cup*, *spoon-sock*, *car-shoe*). Each object pair was presented four times during

the experiment, and each object was named on two trials, once on the left and once on the right of the screen. The order of trials was randomized for each infant.

## Procedure

The procedure was identical to Experiment 1, except for the dimensions of the laboratory, which differed to Experiment 1. Infants sat on their parent's lap facing a widescreen display (0.7 x 0.4 m) with their eyes at a distance of approximately 0.65 m, and at an equal horizontal distance from both images. Images were positioned at a distance of 50 cm center-to-center, each with a display size of 20 x 15 cm.

**Scoring** Digital videos were coded offline on a frame-by-frame basis (every 40 ms) by a skilled blind coder. Every fixation was coded as either left looking, right looking or other looking.

## Results and Discussion

Parental report of vocabulary was similar to that for Experiment 1. Mean comprehension vocabulary was 25 words (*Range* = 1 - 159 words), and mean production vocabulary was 1 word (*Range* = 0 - 4 words). Parents reported low levels of comprehension for the six familiar object labels used in the study: Ball (21 %), Car (25 %), Cup (0 %), Shoe (8 %), Sock (13 %), and Spoon (8 %).

A proportion of target looking measure was calculated by dividing the total duration of fixations to the target (i.e., named) object by the total duration of fixations to both objects. This measure was calculated for each of the four 2.5 s trial phases. A mixed-model ANOVA with the factors of trial phase and a median split on comprehension vocabulary did not reveal any significant main effects or interactions (even with the exclusion of the comprehension vocabulary factor there was no significant effect of trial phase).

We further compared the proportion of target looking to chance for each trial phase. Although there was a preference for the target object during the 5.0 – 7.5 s trial phase,  $M = 53.3\%$ ,  $SD = 7.5$ ,  $t(23) = 2.14$ ,  $p = .043$ , this effect was not significant when adjusted for multiple comparisons. Hence, the results of Experiment 2 do not provide any compelling evidence that infants in Experiment 1 might have known the names for the familiar objects.

## General Discussion

In Experiment 1, we investigated 10-month-olds' attention to familiar and novel objects according to whether they heard a novel label, a familiar label, or a neutral phrase. If novel labels cause greater attention to a novel object than either familiar labels or a neutral phrase, this would suggest the operation of ME at 10 months. However, at an age prior to any substantial vocabulary development, the ME response might be a general constraint on learning, rather than a specific word-learning strategy.

To understand what mechanism could create a mutual exclusivity response at 10 months of age, we looked at

whether infants knew the names of the six familiar objects used in Experiment 1. Parental vocabulary report and infants' looking behavior during Experiment 1 suggested that the infants did not know the names for the familiar objects. Experiment 2 also did not provide any strong evidence that 10-month-olds knew the names for the familiar objects.

Therefore, the evidence favours an explanation of novel label trials where infants do not need to know the name of the familiar object. A general learning constraint, such as latent inhibition (Lubow, 1973, 1989), could account for the infants' behavior during novel label trials, without requiring retrieval of the familiar object names. Infants might attend to a novel object more when they hear a novel label than when they hear a familiar label, because the novel label is relatively easier to associate with the novel object.

An explanation of the 10-month-olds' behavior based on object novelty could account for the discrepancy with Halberda (2003), who found that 14-month-olds increased attention to a *familiar* object upon hearing a novel label. The 10-month-olds appear more adept than older infants at attending to a novel object in response to a novel label. However, the mechanism underlying the observed effects could differ between these ages. While a basic constraint on learning might operate at 10 months, by 14 months of age, a specifically linguistic constraint might underpin the ME response. Thus, 14-month-olds could be working through a more complex sequence of computations than 10-month-olds.

One might ask why 10-month-olds do not have larger vocabularies, if a novel label enhances their attention to a novel object? Some researchers (e.g., Carey & Bartlett, 1978; Mervis & Bertrand, 1994) have argued that the ability to map novel labels to novel objects is a mechanism for 'fast-mapping': the rapid acquisition of novel word meanings. How might we reconcile what 10-month-olds do in the laboratory with their level of language development? One consideration is that while there might be a mechanism favouring attention to a novel object upon hearing a novel label, 10-month-olds might only retain a weak association, if any.

The bias to attend to novel objects in response to novel labels might not be contributing to vocabulary development at 10 months of age. However, this bias might be a precursor to the development of a language-specific principle. ME might emerge from the interaction of a basic learning mechanism, such as latent inhibition, with the linguistic environment. A later-developing principle, geared to the task of learning language, might produce more robust word mappings. Nevertheless, the selective attention to novelty required for this particular word-learning task might be in place at the earliest stages of vocabulary development.

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