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Review

The role of redundant verbal labels in 8- and 10-month-olds' working memory

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ABSTRACT

Verbal labels have been shown to help preverbal infants' performance on various cognitive tasks, such as categorization. Redundant labels also aid adults' visual working memory (WM), but it is not known if this linguistic benefit extends to preverbal infants' WM. In two eye-tracking studies, we tested whether 8- and 10-month-old infants' WM performance would improve with the presence of redundant labels in a Delayed Match Retrieval (DMR) paradigm that tested infants' WM for object-location bindings. Findings demonstrated that infants at both ages were unable to remember two object-location bindings when co-presented with labels at encoding. Moreover, infants who encoded the object-location bindings with labels were not significantly better than those who did so in silence. These findings are discussed in the context of label advantages in cognition and auditory dominance.

1. Introduction

In the domain of cognition, language holds a privileged status among other auditory and communicative signals. This is evident early in life, before children learn to produce language. Infants as young as three months are able to form object categories from labeling phrases but not from tones (Balaban & Waxman, 1997; Ferry et al., 2010). At seven months, infants are able to abstract rules from speech sounds but not from tones (Marcus et al., 1999). At one year, infants are able to use labels but not emotional expression to individuate objects (Xu et al., 2005), and show enhanced activation in visual cortices to objects with a label they know relative to objects with a label they have yet to acquire (Gliga et al., 2010). Infants go on to demonstrate the ability to extend a category from a single labeled exemplar (Pomiechowska & Gliga, 2019), and by age 2–3 years, labels facilitate analogical reasoning (Christie & Gentner, 2014) and visual search (Vales & Smith, 2015). Despite this breadth of research, fewer studies have examined the role of labels in infants' working memory (WM), particularly when these labels are redundant. This paucity is surprising, because adults use redundant labels when memorizing an array of visual items, and do so virtually automatically (e.g. Baddeley et al., 1984; Stefurak & Boynton, 1986; Donkin et al., 2015). Consider the game *Simon* (Hasbro), in which four colored panels illuminate in increasingly longer sequences for a player to repeat by tapping. The player might label the light color "blue…green…red…yellow…" in their head or aloud as they appear in efforts to better encode the order of the colored lights. While it is clear that infants do not engage in this kind of verbal rehearsal, it is plausible that labels might confer memory benefits in the same manner that they confer benefits in other cognitive tasks. In the current study we investigated the role of labeling in WM in very early language learners: 8- and 10-month-old infants, who have

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only just acquired the first words in their receptive vocabulary (Bergelson & Swingley, 2012).

Without labels, infants' WM is both fragile and limited. At 6 months, infants can only remember the identity of a single object (Kaldy & Leslie, 2005; Kwon et al., 2014). Between 8 and 10 months, they are able to remember both the identity and location of two objects (depending on the maintenance interval; Kaldy & Leslie, 2005; Kaldy, Guillory & Blaser (2016); Kwon et al., 2014; Oakes et al., 2006), and by 12 months can remember the identity of three distinct objects (Feigenson & Carey, 2003; Feigenson & Halberda, 2008). These memory representations are fragile—when WM capacity is overloaded, the representations degrade rapidly in a process called catastrophic forgetting. That is, a 13-month-old may remember three items, but if presented with a fourth, will lose all retention of the first three items (Barner et al., 2007; Feigenson & Carey, 2003; 2005). Given these limitations, infant WM stands to benefit from additional cues like object labels, which may strengthen an individual representation and/or allow them to overcome a capacity limit.

A small number of studies have addressed role of labels on infants' memory, and they have demonstrated success from a young age. Two such studies have shown that young children can use labels to reduce memory demands for object identities via chunking. At 14 months, infants were able to use labels to chunk an array of four visually identical items into two pairs, leading to successful memory for four items despite their putative three-item capacity (Feigenson & Halberda, 2008). Moreover, Kibbe & Feigenson (2014) showed that 2–3-year-old toddlers are able to use labels to recode object arrays into a single chunk, thereby increasing their WM capacity to as many as five items. However, it is currently unknown if labeling benefits extend beyond chunking, which is not always a viable memory strategy. In addition to object identity, language has been shown to aid memory for location in young children. By 3–4 years, use of spatial terms led to improved performance on memory for an object's location—this was true even if the children did not know the meaning of the label (Dessalegn & Landau, 2008, 2013; Loewenstein & Gentner, 2005).

The current study differs from past work on labels in infants' memory in a few key ways. The youngest children tested in prior work were 14 months, and presumably speaking at least one word. The focus of the current study is on even younger infants, 8- and 10-month-olds, who have only a small receptive vocabulary (Bergelson & Swingley, 2012). Prior work on object identity has also been limited to the use of labels for chunking (Feigenson & Halberda, 2008; Kibbe & Feigenson, 2014), whereas we focus here on redundant labels that add no additional information. Finally, prior work has assessed memory for an object's identity (Feigenson & Halberda, 2008; Kibbe & Feigenson, 2014) or location (Dessalegn & Landau, 2008, 2013; Loewenstein & Gentner, 2005). In the current paradigm, we assess the successful binding of the object identity *and* location ("what was where?").

In the context of the literature discussed thus far, we anticipated that labels would improve infants' WM. However, it was also possible that redundant labels could have negative effects on memory encoding. Work by Robinson, Sloutsky, and their colleagues have argued that labeling is only beneficial to infants under 16 months when held in contrast to nonlinguistic auditory stimuli, and that performance on these cognitive tasks is even better when no auditory stimuli are presented at all (Robinson et al., 2012; Sloutsky & Robinson, 2008). For example, although infants categorize objects better when presented with labels than tones (Balaban & Waxman, 1997; Ferry et al., 2010), they also categorize better in a silent condition than a labeled one (Robinson & Sloutsky, 2007). Similar results have been found for object individuation (Robinson & Sloutsky, 2008). This phenomenon, termed auditory dominance, suggests that when encoding multimodal stimuli, the visual and auditory systems compete for attentional resources and the auditory system wins (Robinson & Sloutsky, 2019). Infants are unable to direct sufficient resources to processing the visual component of the stimuli, and thus perform more poorly in visual tasks than they would in the absence of labels.

The current study examined whether or not redundant labels lead to better performance on a WM task in two groups of infants: 8- and 10-month-olds. Infants in this age range have demonstrated knowledge of a small group of object labels (notably, food and body parts; Bergelson & Swingley, 2012). Additionally, gains in WM capacity occur in this age range, with 10-, but not 8-month-olds, able to hold two object-location bindings in WM on a Delayed Match Retrieval task (DMR; Kaldy et al., 2016; see also Cheng et al., 2019). We conducted two studies to test two predictions on the role of labels in infants' WM. In Study 1, we tested the effect of redundant labels using labels that infants know (drawn from Bergelson & Swingley, 2012) with 8-month-old infants who were previously shown not to be able to succeed in an object-location WM task without labels. In Study 2, we hypothesized that 10-month-olds, who have shown to be successful without labels in this task, would demonstrate better performance on the DMR with labels.

2. Study 1

Previous research suggests that in typical visual WM tasks, 8-month-olds have a capacity of one object-location binding (Kaldy et al., 2016; Kaldy & Leslie, 2005). A recent eye-tracking study by Kaldy et al. (2016) used the Delayed Match Retrieval (DMR) paradigm to test 8- and 10-month-old infants with two, non-matching, virtual playing cards. Those cards were flipped over, and a third card was presented that matched one of the two from the previous pair. Findings demonstrated that 10-month-old infants made anticipatory looks to the matching card during the delay period, suggesting that they remembered the object-location bindings of each card. Eight-month-old infants did now show a preference to either of the two cards.

The goal of Study 1 was to determine if the addition of redundant labels would increase 8-month-olds' performance on the DMR above chance levels. We adapted the paradigm to include auditory labels that accompanied the presentation of the objects on the cards (and thus, would improve encoding). We hypothesized that unlike in Kaldy et al. (2016), infants in this task would make anticipatory looks to the match card during the delay period, significantly preferring it above the non-match card.

2.1. Method

2.1.1. Participants

Participants were 19 healthy, full-term infants (8 females) ranging in age from 7;00–8;24 (M = 7;19; SD = 15.8 days). Two additional infants participated, but were excluded for fussiness. For comparison purposes, we also retrieved the data from Kaldy et al. (2016)[1] . Their sample included 14 8-months olds (6 females) ranging in age from 7;11−8;18 (M = 7;30; SD = 13.2 days). The infants in the Kaldy et al. (2016) study comprise the No Labels group, whereas the infants in the current study comprise the Labels group. The sample size was selected based on a power analysis using effect sizes from Kaldy et al. (2016). The reported effect size for the group that performed significantly above chance in the Kaldy et al. (2016) study (10-month-olds) was Cohen's $d = 0.787$. With an alpha = .05 and power = .80, the projected sample size required is approximately N = 12 (using G*Power 3.1.9.2; Faul et al., 2007). Consequently, our sample size is adequate for testing whether our sample performed above chance. As for the comparison of two groups (Label/NoLabel), no prior studies can give us benchmark effect sizes, but based on the comparison between 8- and 10-month-olds ($d = 1.207$) in Kaldy et al. (2016), our current sample sizes would provide above 90 % power. Families of participants were recruited for the current study from the [redacted] area based on data from state birth records. Families received $20 and a small gift for participation. All of the participants recruited for the current study were from households in which English was spoken >70 % of the time. Language exposure data were not reported in Kaldy et al. (2016). In compliance with the [redacted] Institutional Review Board, informed consent was obtained from each participant's legal guardian.

2.1.2. Stimuli

Stimuli included virtual depictions of playing cards that contained pictures of familiar objects (an apple, a baby spoon, a baby bottle, and a human hand) on the face side (see Fig. 1a). On any given trial, the apple and spoon were always paired together, and the bottle and hand were always paired together. In addition to being familiar, infants in the 6–9 months age range have been demonstrated to know the labels for these objects (Bergelson & Swingley, 2012). On the back side, the card had a blue texture. Cards were 146 × 146 pixels and subtended a 3.65 degree visual angle. In addition to the visual stimuli, each card was accompanied by a recording of a female voice (recorded by a native English speaker, using infant-directed speech) that labeled the objects on the cards during the presentation of the memory set (e.g. *Look at the apple! Look at the spoon!)*. All speech recordings were controlled for duration.

2.1.3. Apparatus & procedure

Eye movements were recorded using a Tobii T120 eye tracker sampling at 60 Hz. Stimuli were displayed on a 17-inch (43.1 cm) screen with a resolution of 1024 × 768 pixels. Participants sat on a caregivers' lap ~60 cm from the eye tracker in a dimly lit testing room. Caregivers were asked to wear a visor covering their eyes to prevent them from viewing the screen. Infants were calibrated to the eye tracker using a standard 5-point-calibration procedure before each block.

Infants were presented with a Delayed Match Retrieval paradigm, an anticipatory looking paradigm that measures WM for two object-location bindings (Kaldy et al., 2016). In this task, participants were presented with three virtual playing cards with identical backs but different faces. First, they saw the memory set: two cards that have two different objects on the face. These cards then flipped over and the participants were shown a third, sample card, which was an identical match to one of the two cards in the memory set. After a brief response period, the matching card in the memory set briefly animated (visual reward) and revealed its matching face. Anticipatory looks to the match card during the search period indicate a successful WM representation of the object/location binding.

Similarly to the procedure used in Kaldy et al. (2016), infants were first presented with four familiarization trials (Fig. 1b). In these trials, all three cards (the memory set and the sample) entered the screen, but only one card in the memory set (the match) was shown to the infants. Infants were given 2.5 s to encode this object, and it remained face up. During this encoding period, the object on the card's face was labeled once by a pre-recorded female voice, playing through a centrally located speaker (e.g. *Look at the bottle!*). Then, the sample card flipped over, revealing its matching face (which was not labeled). After 200 ms, the match card was revealed and was followed by a brief reward animation (for 200 ms). This reward was so brief that infants needed to have made an anticipatory eye movement to the (face-down) match card's location in order to fixate it; an implicit instruction ('look for the match to catch the reward animation!'). Then, the matching cards remained face-up and left the screen in an exit sequence. In the exit sequence, the match card moved next to the sample, "kissed" it, and all three cards exited the screen. Each of the four stimuli served as the sample/match card on one of the training trials; order was counterbalanced.

These familiarization trials were followed by 10 test trials (see Fig. 2), which began in a similar manner with all three cards entering the screen. This time, both cards in the memory set were flipped sequentially, such that the first card was presented for 2.5 s, then the second card was presented for 2.5 s, then both cards were flipped back over. We used this sequential presentation method to make sure that infants fixated both of the cards during this phase. As with training trials, the presentation of each card in the memory set coincided with an auditory labeling sentence (e.g. *Look at the apple!*). All three cards remained face-down for 1 s before the sample card was revealed (similarly to the familiarization trials, unlabeled). The sample presentation was followed by a 4 s response period in which participants' anticipatory looks to both (face-down) cards in the memory set were measured. At the end of the response period, the match card was briefly exposed, followed by the brief visual reward sequence, and the same exit sequence as in the familiarization trials.

All trials (both familiarization and test) had a gaze-contingent onset. Trials were preceded by an attention-getter (a spinning fixation cross at the center of the screen), which infants looked at in order to start each trial. The stimulus pairs (apple-spoon, bottle-hand), which card served as the sample/match, and the location of the match (left or right side) were all counterbalanced. Trial order was randomized through Tobii Studio, which uses a Latin square procedure.

[1] There were a few minor differences in the methods of these two studies (most notably, in the stimulus set), which we will return to in our Discussion.

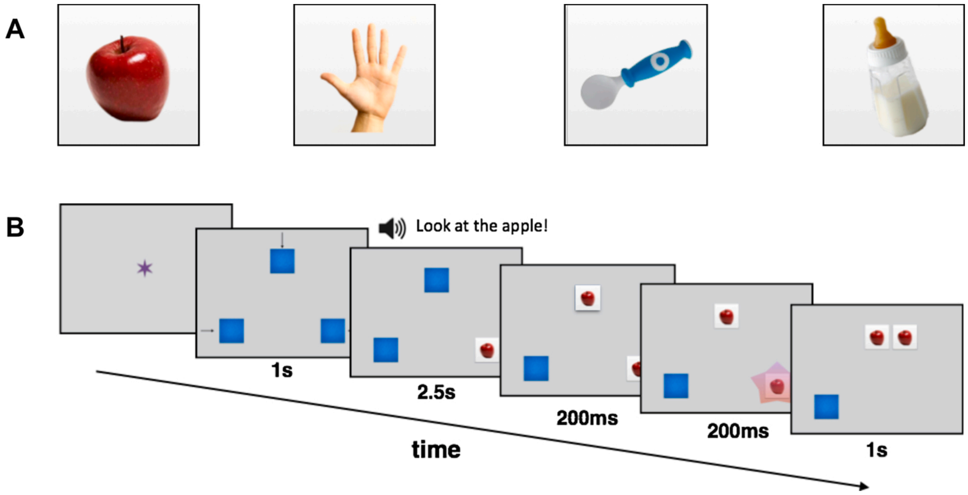

Fig. 1. (A) Faces of Cards Used in Familiarization and Test, (B) Schematic of Familiarization Trial in Studies 1 and 2.

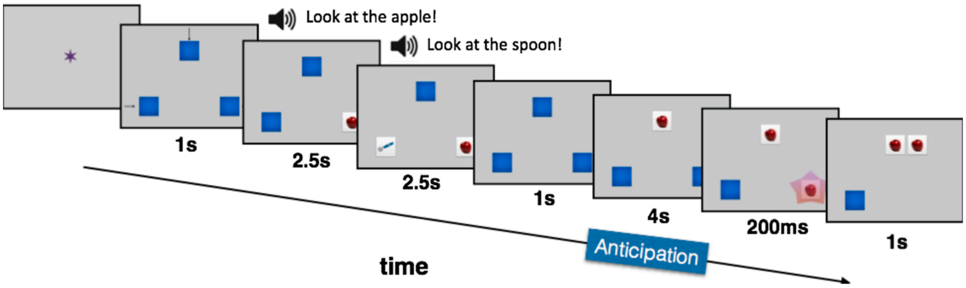

Fig. 2. Schematic of Test Trial in Studies 1 and 2.

2.1.4. Data analysis

We defined three same-size square AOIs (292 × 292 pixels) centered around the two cards in the memory set as well as the sample card. Time to first fixation and total look duration to each AOI were measured during the 4 s response period in each test trial. From these measures we calculated two main variables of interest: First Look and Proportion of Looking Time to the Match. First Look was calculated by comparing the time to first fixation on the match and non-match card, and determining which occurred first. The number of trials in which a participant made their first look to the match was then summed and divided by the number of trials to get a proportion (values range from 0 to 1, with 1 meaning all first looks were to the match card). Proportion Looking Time was calculated trial-by-trial by dividing the total look duration to the match card by the sum total look duration to either the match or nonmatch card. This was then averaged across trials, by participant. Trials in which participants did not make an anticipatory fixation to either card were excluded from analysis (30.5 % of trials were excluded for this reason). All participants were required to contribute at least 3 trials (30 %) to be included in the analysis.

2.2. Results

To determine if 8-month-olds succeed on the DMR paradigm with redundant labels, we first conducted the same analyses carried out by Kaldy et al. (2016). We conducted two one-tailed, one-sample t-tests, comparing First Look and Proportion Looking Time to chance (.5), with the prediction that both measures will be significantly greater than chance. Greater than chance looking to the match card is evidence of success on the DMR. Findings demonstrated that neither First Look ($t(18) = -1.48$, $p = .92$, $M = .45$, $SD = .15$, 95 % CI = [.39, Inf]), nor Proportion Looking ($t(18) = -1.09$, $p = .85$, $M = .46$, $SD = .15$, 95 % CI = [.4, Inf]) measures were greater than chance.

To determine if these participants out-perform the 8-month-old infants in the Kaldy et al. paradigm, we conducted a one-tailed, independent samples *t*-test comparing First Look and Proportion Looking Time across the Labels (current study) and No Labels (Kaldy et al., 2016) groups (Fig. 3). The goal of this analysis was to determine if labels provided a benefit to 8-month-olds, as compared to those who previously failed the task without labels. Findings demonstrated no significant differences between groups on First Look ($t(30.95) = -.12$, $p = .91$, 95 % CI = [-.1, .09]), nor Proportion Looking ($t(30.58) = -1.13$, $p = .27$, 95 % CI = [-.16, .04]) measures.

3. Study 2

The goal of Study 2 was to determine what, if any, effect object labels have on infants' WM representations when they are within their WM capacity. 10-month-olds have previously demonstrated successful memory for two object-location bindings without redundant labels. However, their prior performance on the DMR, while significantly above chance, averaged only 61.66 % on First Look (Kaldy et al., 2016). This average suggests that they failed to make anticipatory looks to the match card nearly 40 % of the time—this could potentially be improved if their object representations were more robust. To test this hypothesis, we conducted a DMR paradigm on two groups of 10-month-old infants: one who got redundant labels at exposure (identical to the Labels group in Study 1) and one that did not (a control group, conceptually akin to Kaldy et al., 2016). We hypothesized that if labels improve infants' performance, the Label group would outperform the No Label group. If instead labels interfere with visual WM encoding, the No Label group would outperform the Label group. Finally, if labels have no effect, performance will be equal in the two groups (and the same as in Kaldy et al., 2016).

3.1. Method

3.1.1. Participants

Participants were 34 healthy, full-term infants (14 females) ranging in age from 9;01–10;30 (M = 9;25; SD = 12.6 days). Nine additional infants participated, but were excluded for fussiness. Sample size was determined to be adequate using the same power analysis as in Study 1. Participants were assigned to one of two groups: Labels (n = 18) or No Labels (n = 16). Participants that were

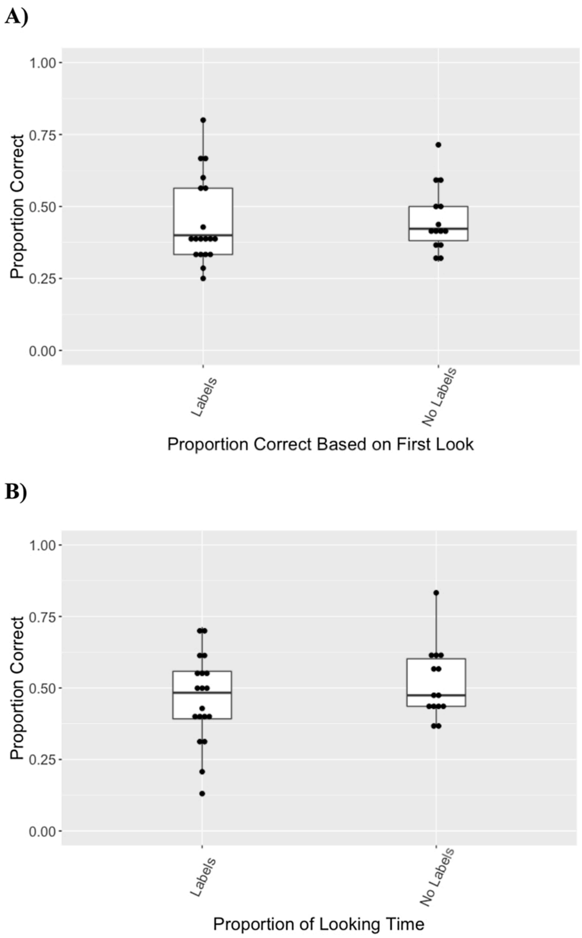

Fig. 3. Proportion correct performance based on First Look (A) and Proportion Looking Time (B) in Study 1. Dots represent individual participants.

from dominantly (>70 %) English-speaking households were randomly assigned to each group (n = 28). Participants that came from households that did not meet this threshold (n = 6) were assigned to the No Label group[2] . Recruitment, consent, and payment procedures were identical to Study 1.

3.1.2. Stimuli, apparatus & procedure

For the Label group, the stimuli, apparatus, and procedure were all identical to Study 1. For the No Label group, study features were also identical with the exception of the labeling phrases at encoding. The faces of the cards were presented in silence to this group.

3.1.3. Data analysis

All data processing procedures and variables were identical to Study 1. As in Study 1, participants were required to contribute at least 3 valid trials (participants had to make at least one anticipatory fixation to either card in the memory set) to be included in the final sample.

3.2. Results

To determine if 10-month-olds' performance improves on the DMR paradigm with redundant labels, we compared anticipatory looking behavior between the two groups. We conducted two one-tailed, independent samples t-tests, comparing First Look and Proportion Looking Time across groups, with the hypothesis that the Label group would out-perform the No Label group on both measures (Fig. 4). Findings demonstrated that there were no significant differences between the two groups on either First Look ($t(27.5) = -.68$, $p = .75$, 95 % CI = [-.16, Inf]) or Proportion Looking Time ($t(31.23) = 1.15$, $p = .13$, 95 % CI = [-.033, Inf]). A post-hoc exploratory analysis demonstrated that the No Labels group was not significantly different from chance on First Look ($t(15) = 1.70$, $p = 0.055$, $M = .56$, $SD = .14$, 95 % CI = [.5, Inf],). Because these results are close to the traditional p-value cutoff of significance and numerically similar to those found in Kaldy et al. (2016), we conducted a Bayesian one-tailed t-test to determine the meaningfulness of this result. Findings demonstrated that the alternative hypothesis is ~1.5 times more likely than the null hypothesis ($BF_{10} = 1.54$), which is considered weak or anecdotal evidence of the alternative hypothesis (Dienes, 2014). The No Labels group was not significantly different from chance on Proportion Looking Time ($t(15) = -.33$, $p = .63$, $M = .49$, $SD = .18$, 95 % CI = [.41, Inf].

Finally, we examined the role of labels in performance across age groups (8-month-olds in Study 1 and 10-month-olds in Study 2). We used two-tailed independent-samples t-tests to compare First Look and Proportion Looking Time across the Labels groups from each study. We hypothesized that the 10-month-olds would out-perform the 8-month-olds on both measures. Findings demonstrated that this was not the case. The 10-month-olds were not significantly different from the 8-month-olds on measures of First Look ($t(27.8) = -.95$, $p = .35$, 95 % CI = [-.20, .07]) nor Proportion Looking Time ($t(33.87) = -1.74$, $p = .09$, 95 % CI = [-.2, .02]).

3.3. Discussion

The overarching goal of these studies was to determine if redundant labels for familiar objects would facilitate WM performance in preverbal infants. In two studies, we demonstrated that this hypothesis was inconsistent with data from both 8- (Study 1) and 10-month-olds (Study 2). When presented with labels at encoding, infants in both age groups failed to make anticipatory looks to the match card above chance levels. Ten-month-olds who encoded the stimuli in silence did not perform significantly worse than 10-month-olds who were presented with concurrent labels, and surprisingly, they were not better than chance. These findings are not consistent with an account of labels benefiting WM in preverbal infants.

We hypothesized that labels would benefit infant WM because prior work has demonstrated that redundant labels are beneficial to preverbal infants in other cognitive domains (e.g. Ferry et al., 2010). There are a number of reasons why this label superiority account may not have extended to our WM task. One possibility is that WM is an exception among cognitive skills, and infants at this age do not receive WM advantages when presented with labels. However, a narrower interpretation is possible, based on task demands. The Delayed Match Retrieval paradigm requires infants to not only remember the identities of the objects in the memory set, but also where each was located. Thus far, object labels have only been shown to benefit object-related processes (e.g. individuation, categorization, and recognition), but not object-location-binding processes. We did not use any spatial language, which has been shown to improve memory for object locations in 4-year-old children (Dessalegn & Landau, 2008, 2013). Thus, it is possible that labels could improve the encoding of objects themselves at this age, but not improve (or even interfere with) encoding of their locations. Indeed, prior research has suggested that communicative contexts engender memory biases for object identity whereas non-communicative contexts engender memory biases for object location (Yoon et al., 2008), although the replicability of this finding has recently been called into question (Silverstein et al., 2019).

The primary theory competing with label superiority is auditory dominance (e.g. Robinson & Sloutsky, 2007; 2008), and our findings do not provide clear evidence for this account either. Whereas 10-month-olds who received redundant labels performed

[2] This is akin to the procedure used in Kaldy et al. (2016) which, as it has been typical in infant cognition studies to date, did not exclude any participants on the basis of language exposure and did not analyze the effect of this factor (but see Byers-Heinlein (2019) for arguments for why this practice should change). For this study, we conducted analyses comparing performance by participants who did and did not meet the threshold for a monolingual English household. Findings showed no differences. However, this analysis in our current design is underpowered; we cannot rule out the possibility that language exposure may play a role.

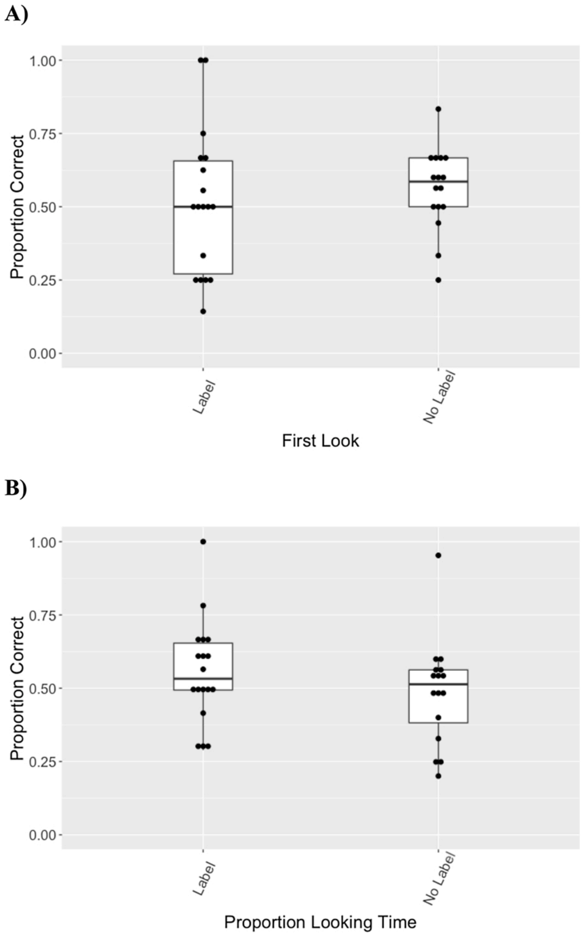

Fig. 4. Proportion correct performance based on First Look (A) and Proportion Looking Time (B) in Study 2. Dots represent individual participants.

poorly on the task in Study 2, their performance was not significantly different from 10-month-olds who did not receive labels. This group similarity is consistent with prior work on long-term visual memories in infants, in which 14−22-month-olds in silent and labeled conditions were not significantly different from each other in novelty preference (Robinson & Sloutsky, 2019). Together, these findings imply that memory may be an exception to the auditory dominance account in infancy. However, the infants in Robinson and Sloutsky's (2019) study both performed significantly above chance, in contrast to the infants in the current studies. Additionally, work on categorization, in which the auditory dominance effect was found, used a much larger sample size than the current study (Robinson & Sloutsky, 2007).

A remaining consideration is that none of the groups of infants in the current study performed significantly above chance, in contrast to findings from Kaldy et al. (2016). In that study, 10-month-olds were not presented with labels and performed significantly above chance, whereas the 10-month-olds in the current study were only slightly better than chance on First Look ($M = .56$, $p < .055$, $BF_{10} = 1.54$), and not better than chance on Proportion Looking Time. That the First Look findings were numerically similar (within the 95 % confidence interval of the original study) and in the same direction suggests that these studies are potentially comparable. It is clear is that the effect sizes in the current study are smaller (although still within the "medium" range, $d = .42$ in the current study vs. $d = .76$ in the original). The differences in findings could be attributed due to two methodological differences between the two studies. A different set of stimuli was used: four everyday objects were used in the current study whereas two abstract shapes (a nautical star and a swirl shape) and two recognizable shapes (a tree and a smiley face) were used in Kaldy et al. (2016). Changing the stimuli was necessary for the label condition in the current study. Abstract shapes are inherently unnamable and outside of infants' presumed vocabularies. In addition, there were two blocks of trials in Kaldy et al. (2016), but here only one block of trials was used. However, successful performance was observed by Kaldy et al. (2016) with 10-month-olds in the first block as well as the second, so we believe this is an unlikely explanation. All other training and test procedures were the same.

Another possibility for the difference between studies may be an overestimation of effect size in the original study. Overestimation of effect size is common among seminal developmental studies (Bergmann et al., 2018). A post-hoc power analysis suggests that if the No Label group truly performs above chance at the effect size detected in Study 2 ($d = .42$, rather than $d = .76$ in the original study), 36 infants would be required in that condition alone to achieve a power level of .8. If that is indeed the case (that no labels leads to above chance WM performance and the current study is underpowered), we would expect a higher-powered study to yield evidence in favor of the auditory dominance account. Clearly, future research is warranted.

In sum, the findings presented here contribute to the existing literature demonstrating that preverbal infants' WM is still fragile (for successful performance in a similar paradigm in slightly older, 13-month-old infants, see Cheng et al., 2019). Here, we showed that redundant labels presented at encoding did not help 8- and 10-month-olds overcome this fragility. This finding suggests that at this age, redundant labels do not confer a WM advantage, unlike in other cognitive domains (such as categorization). However, the current findings do not provide strong support for the earlier finding that 10-month-olds can hold two object-location bindings in WM *without* labels. Whether or not redundant labels *hinder* preverbal infants' performance on working memory tasks remains unanswered. We believe that future research should continue to pursue this inquiry, given that infants encode objects in a wide variety of multimodal contexts (e.g. book reading, the introduction of a new toy, etc.), and the possibility that labeling objects actively could hinder encoding of visual representations in very young infants remains an important open question.

Author statement

Allison Fitch: Conceptualization, Methodology, Software, Formal analysis, Investigation, Data Curation, Writing, Visualization. **Nilam Thaker:** Software, Investigation. **Zsuzsa Kaldy:** Conceptualization, Methodology, Resources, Writing, Supervision, Funding acquisition.

Declaration of Competing Interest

The authors declare no conflict of interest.

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