The Effect of Labels on Categorization: Is Attention to Relevant Features A Good Index of Infants' Category Learning?

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Abstract

Shifting attention to category relevant features has been demonstrated in adults to be a successful strategy for categorizing novel objects. The current experiment was aimed at exploring whether infants would use a similar strategy for category learning when objects were presented with and without labels. Using an eye tracker, 6- to 8-month-old infants were familiarized and tested with a novel visual category where only half of the features were relevant for category membership. There was some evidence that infants learned the target category only when objects were not labeled. Furthermore, infants who learned the target category did not appear to optimize their attention to the category relevant features. In addition, contrary to some theoretical accounts, there was no evidence that labels facilitated categorization by highlighting category relevant features.

Keywords: Categorization; Attention; Language; Infants

Introduction

Categorization, the ability to treat discriminable items as similar, is a critical skill for making sense of the visual world. One strategy for successful categorization of new information is to optimize attention to features that may predict category membership and away from features that may not predict category membership. Selectively attending to category relevant information while ignoring category irrelevant information has been demonstrated by human adults and non-human animals (e.g., Dixon, Ruppel, Pratt, & De Rosa, 2009; Mackintosh, 1965). Adults tested in a categorization task with an eye tracker demonstrated attention optimization when they attended selectively to the relevant features of a category during learning trials (Hoffman & Rehder, 2010). It is less clear, however, whether infants have the ability to optimize their attention in a similar way as adults. Some research suggests that infants would be less likely to engage in selective attention due to an immature prefrontal cortex, which is responsible for executive functions such as selective attention (e.g., Posner & Petersen, 1990). Sloutsky (2010) further argues that because the prefrontal cortex matures later in the course of development, infants (who are known to categorize visual input) ought to learn categories through means other than selectivity. Therefore, the assumption that infants, like adults, should optimize their attention to relevant features over the course of learning may not be plausible based solely on the prematurity of the prefrontal cortex. However, there is research suggesting that linguistic labels may help infants shift attention to relevant features during categorization by focusing infants' attention on perceptual features that are shared by members of a category. If labels can direct attention to commonalities among category members, then infants should optimize their attention to relevant features over time. Previous research demonstrates that infants ranging from 3 to 12 months are often better at learning visual categories when objects are associated with labels than when the same visual stimuli are associated with nonlinguistic sounds (Balaban & Waxman, 1997; Fulkerson & Waxman, 2007; Robinson & Sloutsky, 2007; Ferry, Hespos, & Waxman, 2010). However, labels have also been shown to attenuate infants' learning of visual categories when performance was compared to learning of unlabeled objects presented in silence (Robinson & Sloutsky, 2007).

What underlying mechanisms can account for the facilitative effects of labels on infants' categorization? It has been argued that labels facilitate categorization by highlighting the commonalities among labeled entities (Fulkerson & Waxman, 2007; Waxman, 2003) and that labeling objects directs attention to perceptual properties that will aid successful categorization (Waxman, 2004). In contrast, some researchers argue that infants have difficulty processing multimodal information, with labels often attenuating visual processing early in development (Robinson & Sloutsky, 2007; Sloutsky & Robinson, 2008). Therefore by this account, labels should have no facilitative effect above a silent condition and may even overshadow infants' visual processing.

One limitation of previous research is that the mechanisms underlying the effects of labels on categorization are often inferred by examining infants' novelty preference at test, rather than directly testing how labels affect attention in the course of category learning.

The few preliminary studies that have recently used an eye tracker to examine how labels affect infants' attention during category learning have yielded mixed results. Althaus and Mareschal (2010) demonstrated that infants attended to the commonalities between category exemplars more when objects were labeled than when presented in silence. However, this research examined infants' looking to category relevant features only in the first second of each familiarization trial (*i.e.*, prior to hearing the label). In a different study, Best, Robinson, and Sloutsky (2010) found that common labels did not direct infants' attention to common features more than a silent control condition. Rather, they found attentional differences only when objects were paired with varying labels such that unique labels directed infants' attention to unique features more than infants in a silent control condition. Finally, Robinson and Sloutsky (2010) found that compared to a silent control condition, labels often attenuated learning of visual categories: When images were labeled, infants exhibited attenuated looking to category relevant features and attenuated preference for a novel category in a subsequent testing phase.

The primary goals of the current study were to examine how labels influenced visual attention over the course of category learning and to examine whether infants, like adults, optimize attention to category relevant features over time. If labels facilitate category learning, then infants should be more likely to learn the category in the label condition. If labels initially interfere with learning, then infants should be more likely to learn the category in the silent condition. Furthermore, if labels direct attention to commonalities, then infants should optimize attention to the relevant features over time. To investigate the effect of labels on infants' attention to category relevant features during a category learning task, half of the infants were familiarized to category members with labels and half were familiarized to category members presented in silence. Critically, half of the visual features on each category member were shared among the category members (*i.e.*, category relevant information); whereas, the other half of the features were not predictive of category membership (*i.e.*, category irrelevant information).

Method

Participants

Forty infants (20 boys, 20 girls) ranging in age from 6 to 8 months (M = 6.85 months, SD = 0.95 months) were tested, with 20 infants in the label condition and 20 infants in the silent condition. Infants were recruited from local birth records. All infants were healthy, and no parents reported any infant to have vision or hearing problems.

Stimuli

Visual stimuli included two categories of objects, each with 10 exemplars. A category member consisted of a large X with four colorful shapes affixed to each end point (see object pairs in Figure 1). For each exemplar, two locations contained consistent colored shapes across category members (*i.e.*, category relevant features), while two locations contained colored shapes that were unique to each category exemplar (*i.e.*, category irrelevant features). Objects were presented in pairs subtending an approximate horizontal and vertical visual angle of 3.8°.

A female experimenter, using infant directed speech, recorded the audio stimuli for the label condition. The speech component was recorded using Cool Edit 2000 at 44.10 kHz, 16 Bit, in stereo. The speech was presented at approximately 68-72 dB.

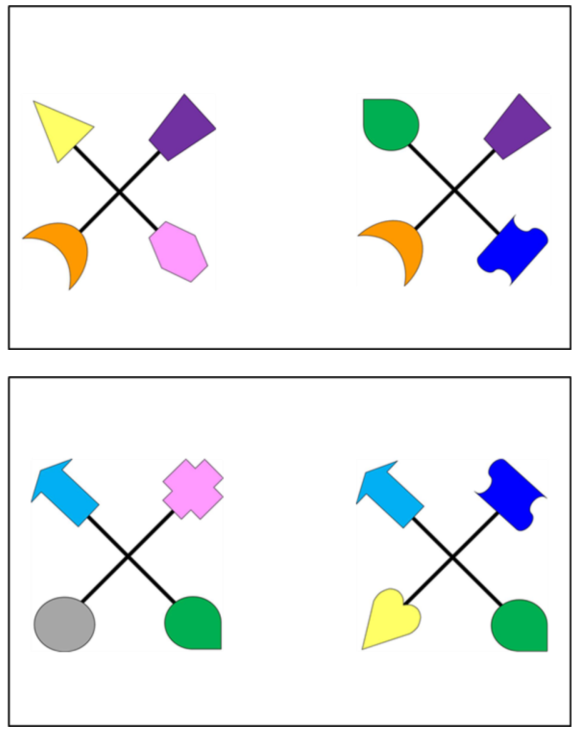

Figure 1. Example stimulus pairs from category 1 (top panel) and category 2 (bottom panel). *Note.* Category relevant features included the trapezoid in the top right corner and the crescent in the bottom left corner for category 1 and the arrow in the top left corner and the teardrop in the bottom right corner for category 2.

Apparatus

A non-invasive Tobii T60 eye tracker measured eye gaze by computing the pupil-corneal reflection at a sampling rate of 60 Hz (*i.e.*, 60 gaze data points collected per second for each eye). The eye-tracking device, which is integrated into the base of a high-resolution 17-inch computer monitor, was located on a table inside a darkened testing booth, enclosed by curtains. A trained experimenter monitored the experiment on a 19-inch Dell OptiPlex 755 computer located outside of the testing booth. A Sony Network camera was located inside the testing booth to the side of the eye tracker displaying a live feed view of the participant that an experimenter monitored on a 9-inch black and white Sony SSM-930/930 CE television. Two Dell computer speakers were positioned behind a curtain and out of view on either side of the eye tracker.

Design

The experiment had a between-subjects design with participants randomly assigned to one of two experimental conditions (*i.e.*, label or silent). Visual input was identical for both conditions and was presented in a random sequence. The presence of auditory input differed between conditions and when included, it varied randomly.

Procedure

Infants sat on a caregiver's lap and were positioned in front of the eye tracker within an approximate viewing distance of 60cm. Prior to the experiment, infants completed a 5-point calibration sequence lasting less than one minute. The calibration points consisted of a dynamic kitten image appearing on the screen with a corresponding "bounce" sound.

Training and test trials were presented in blocks. All participants completed four blocks, with each block having six training trials and one test trial, for a total of 28 trials. Infants were familiarized to one category and tested with a contrasting category. Objects were always presented in pairs. However, during training trials, the object pairs consisted of members of the same category; whereas, during test trials, object pairs included a novel category member and a novel non-category member.

For infants in the label condition, the following six speech phrases were randomly paired with visual images on each trial:

Look at the feps!
Wow, these are feps!
Hey, these are feps!
Do you see the feps?
Can you see the feps?
Look at these!

To minimize differences between training and test trials, infants in the label condition heard "Look at these" on all test trials in addition to hearing "Look at these" once in each training block. This programming detail made the learning and test trials identical apart from the change in visual stimuli. Only infants in the label condition heard auditory input during the trials. Infants in the silent condition never heard speech during the experiment. To maintain engagement, a dynamic bouncing ball was centrally presented as an attention-grabbing fixation between every trial for both conditions.

On each trial, visual images lasted for a total duration of 5000ms for both conditions. In the label condition, the audio occurred with the onset of the image and lasted between 890ms and 1700ms, depending on the phrase. The remaining duration consisted of silence. Infants' looking time data were recorded using E-prime software version 2.0.

Results

Unfiltered gaze data were used to calculate looking time proportions. A point of gaze was recorded if a participant spent at least 16.67ms looking to any of the pre-determined areas of interests (AOIs). The AOIs were defined as a square surrounding the location of the four main parts of each object. Using looking time measures, test data were analyzed first to establish whether infants learned the categories. Training data were then analyzed to identify infants' attention to relevant versus irrelevant features during the course of learning and if there were differential attention patterns between infants in the silent and label conditions.

Test Data

To examine how labels influenced infants' learning of the categories, a traditional measure of categorization was used. Infants' novelty preference (*i.e.*, looking time to the novel category in relation to looking time to the novel and familiar categories combined) was calculated for each trial, and then averaged across all four test trials. Infants' mean novelty preferences in the silent condition ($M = .53$, $SE = .03$) and in the label condition ($M = .52$, $SE = .03$) did not differ from chance (.50).

To further examine dynamics of infants' novelty preferences within test trials, a novelty preference score was calculated every 500ms, and then averaged across the four test trials at each point in time for the total duration of 5000ms. Infants in the silent condition showed a reliable novelty preference for the first 2000ms after stimulus onset, t's > 1.85, p's < .05; whereas, looking to the novel category was never reliably greater than looking to the familiar category for infants in the label condition (see Figure 2).

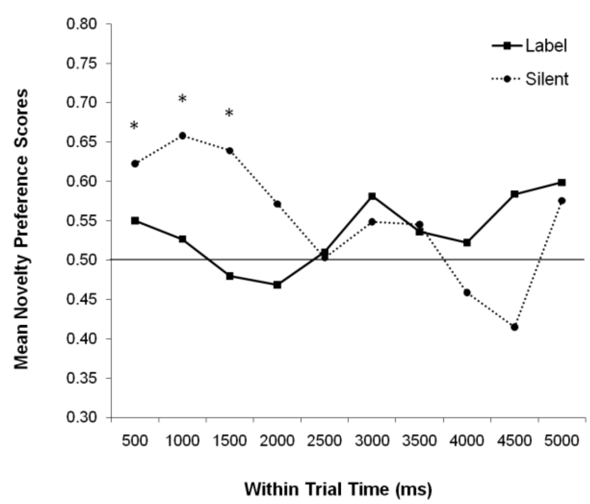

Figure 2. Mean novelty preference scores within test trials. *Note*. The * indicates a reliable difference from .50, $p < .05$.

Furthermore, by looking at individual infants' novelty preferences, it was apparent that the group means were not different from chance because for those infants who discriminated the categories at test, some showed a familiarity preference rather than a novelty preference. To tease this apart, we conservatively classified infants as learners if they demonstrated above chance preferences for the novel category (*i.e.*, ≥ 60%) or if they demonstrated above chance preference for the familiar category (*i.e.*, ≥ 60%). In the silent condition, 65% of the infants were classified as learners; whereas, only 45% of infants in the label condition were classified as learners. Although a larger proportion of infants in the silent condition were classified as learners than in the label condition, this group difference was not statistically significant.

Training Data

To determine how labels influenced infants' visual attention during learning, the proportion of time infants looked at the category relevant features within each training trial (*i.e.*, every 500ms) in relation to the total looking time to category relevant and category irrelevant features combined was calculated. As can be seen in Figure 3, the proportion of looking to category relevant features never exceeded .50 for infants in either the silent or label condition, providing no evidence that labels directed infants' attention to category relevant features compared to the silent condition.

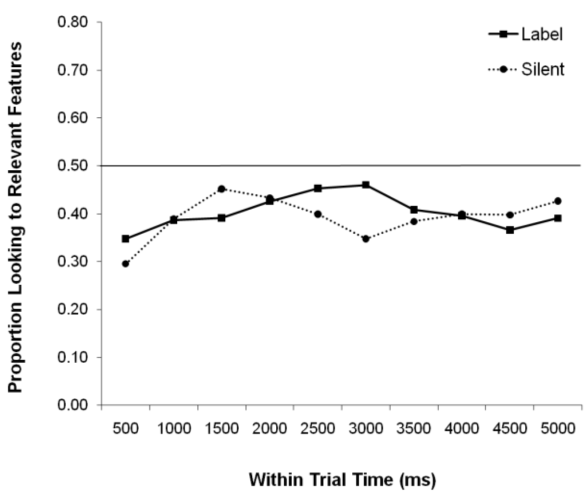

Figure 3. Proportion of looking to category relevant features within training trials.

Infants did not optimize attention to relevant features. Instead, they were less likely to look to category relevant features than to category irrelevant features. Additionally, infants' mean looking to category relevant features collapsed across all fixations was significantly less than .50 in the label condition (M = .40, SE = .02) and in the silent condition (M = .39, SE = .03), t's > 3.73, p's < .01, and at no within trial time point did the infants' mean proportion of looking to relevant features in the label condition exceed infants' mean proportion of looking to relevant features in the silent condition.

Discussion

The current study examined how labels affect categorization by assessing categorization in a traditional preferential looking paradigm during test trials and examining infants' attention to category relevant features in the course of learning during training trials. Several important findings were revealed by the current results. First, there was little evidence that labels have facilitative effects on category learning. Infants in the label condition did not learn the target category. In contrast, infants in the silent condition demonstrated some evidence of category learning with greater initial looking at each test trial to the novel non-category object early in the trials. Second, the current experiment also found no effect of labels directing attention to commonalities during learning. Even in the silent condition where the majority of infants learned the target category, there was no evidence of attention optimization to category relevant features. Infants, unlike adults, did not shift their attention to category relevant features as a strategy for learning to categorize novel objects in the given task. Therefore the current results suggest that attention to relevant features may not be a good index of infants' category learning.

The current study is not without limitations. Traditional novelty preference scores did not differ from chance preferences for infants in either the silent or label condition, suggesting the target category was difficult to learn. Although this null result could be explained by some infants demonstrating a reliable familiarity preference and some infants demonstrating a reliable novelty preference, the lack of a robust group novelty preference at test may have been due to the nature of the stimuli. Whereas spatially separated features provided cleaner eye-tracking analysis of infants' looking to individual features, it may have been more difficult for infants to perceive objects as a whole than if the features had been less spatially separable. If infants did not encode whole objects during training trials, it should be somewhat more difficult to discriminate categories during test trials. It would be beneficial to replicate the current study with different classes of stimuli to clarify this design-related issue.

Although these findings do not support previous evidence of facilitative effects of labels on infants' categorization (Balaban & Waxman, 1997; Fulkerson & Waxman, 2007), they do support previous evidence of attenuated visual processing due to auditory input (e.g., Robinson & Sloutsky, 2007). Studies have shown that labels interfere with visual processing in pre-linguistic infants (Robinson & Sloutsky, 2007; Sloutsky & Robinson, 2008). Yet researchers have suggested that a possible mechanism for labels to facilitate learning is by inviting infants to focus on commonalities among category objects.

However, the current study found no evidence of infants increasing their attention to features that were common between objects in a given object category. Furthermore, whereas selective attention is an efficient means for adults to categorize objects, in the current experiment, those infants who learned the categories did so without optimizing their attention to the relevant features. Infants in the silent condition demonstrated a reliable preference for the novel category within the first two seconds of test trials, yet attention patterns during learning indicate that they spent more time looking to category irrelevant features than to category relevant features. Given that by definition, the category- relevant features remained constant throughout, it is highly likely that infants habituated to the unvarying features and quickly shifted attention to the irrelevant features that were more novel across training trials. This provides further evidence that despite having an immature prefrontal cortex, infants can learn categories through means other than selectivity, as Sloutsky (2010) has argued. One possibility is that infants in the current task learned the pattern of correlations among features. Research has found that infants can abstract correlated features among objects when provided with a sufficient number of exemplars (e.g., Younger & Cohen, 1986). Given these different learning mechanisms, it is important for future research on category learning to consider that signature patterns of attention during learning may differ developmentally.

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