

Mechanisms Underlying the Effects of Labels on Cognitive Development

Christopher W. Robinson (robinson.777@osu.edu)

Center for Cognitive Science
The Ohio State University
208F Ohio Stadium East, 1961 Tuttle Park Place
Columbus, OH 43210, USA

Erica M. Howard (howard.432@osu.edu)

Center for Cognitive Science
The Ohio State University
207D Ohio Stadium East, 1961 Tuttle Park Place
Columbus, OH 43210, USA

Vladimir M. Sloutsky (sloutsky.1@osu.edu)

Center for Cognitive Science
The Ohio State University
208C Ohio Stadium East, 1961 Tuttle Park Place
Columbus, OH 43210, USA

Abstract

It has been argued that labels play a special role in cognitive development: hearing the same label associated with different entities facilitates categorization by directing infants' attention to commonalities. The current study assessed 8-month-olds' attention to commonalities and processing of visual input more generally when visual stimuli were presented without auditory input (baseline), as well as when paired with the same label, the same nonlinguistic sound, and pre-familiarized sound. Labels did affect infants' looking differently than unfamiliar nonlinguistic sounds, however, these effects stemmed from sounds overshadowing (or attenuating processing of) visual input more than labels. Furthermore, when children were pre-familiarized to the nonlinguistic sounds prior to the experiment proper, effects of sounds and labels on processing visual input did not differ. Taken together, these findings suggest that labels may affect cognitive development differently than other types of stimuli because they represent a familiar class of stimuli.

Keywords: Cognitive Development, Attention, Language Acquisition, Psychology, Human Experimentation.

Introduction

Labels appear to play an important part in the way children perceive the world. In particular, it has been demonstrated that labels facilitate category formation and labels help children differentiate object kinds (e.g., Balaban & Waxman, 1997, Xu, 2002, see also Waxman, 2003 for a review). Although these effects are well documented, there are very different proposed mechanisms underlying these effects.

According to one position, even prelinguistic infants are "equipped with a broad, universally shared expectation, linking words to commonalities among objects," (Waxman, 2003, p. 220). For example, Balaban and Waxman (1997)

demonstrated that 9-month-old infants are more likely to form object categories when the objects are presented with the same label, whereas, hearing the same nonlinguistic sound associated with the same objects had no facilitative effect on category formation. In addition, it has also been demonstrated that 9-month-olds are more likely to expect that two objects are hidden behind an occluder when the two objects are associated with two labels than when the two objects are associated with two non-speech sounds or the same label (Xu, 2002). To explain these findings, it has been proposed that infants have assumptions that words are linked to categories and hearing the same label associated with different objects facilitates categorization by directing infants' attention to commonalities and hearing different labels facilitates individuation by directing infants' attention to differences (Waxman, 2003).

Although these studies suggest that labels, but not other types of stimuli, play a special role in cognitive development, there is an alternative explanation that can equally explain the same set of findings without proposing that 9-month-olds have broad assumptions that labels refer to categories. In particular, there is a growing body of evidence suggesting that some auditory stimuli overshadow (or attenuate processing of) corresponding visual input, whereas other stimuli tune or facilitate processing of visual input, and these effects are not specifically tied to linguistic stimuli (Napolitano & Sloutsky, 2004; Robinson & Sloutsky, 2004; Sloutsky & Napolitano, 2003; Sloutsky & Robinson, 2005). These researchers argue that understanding attentional factors underlying cross-modal processing may be fundamental for understanding how labels affect cognitive development.

When infants and young children are presented with unfamiliar sounds and unfamiliar pictures, the auditory input often overshadows the visual input (Robinson & Sloutsky,

2004; Sloutsky & Napolitano, 2003). However, under ample exposure to the auditory-visual compounds, these overshadowing effects disappear when the auditory component is familiar (Sloutsky & Robinson, 2005). Here, 16-month-olds are more likely to discriminate visual stimuli when paired with familiar sounds or familiar words than when the visual images are presented in isolation. These findings suggest that familiarity of the auditory stimulus has larger effects on processing corresponding visual input than whether the stimulus is linguistic or nonlinguistic.

One prediction that can be drawn from these recent studies is that previously reported effects of labels on categorization and individuation may stem from unfamiliar auditory stimuli (e.g., pure tones) overshadowing visual information more than familiar auditory stimuli (e.g., human speech). This hypothesis was recently tested in a study conducted by Tobin, Howard, Robinson, and Sloutsky (2004). In this study, 8- and 12-month-olds were presented with different exemplars from a basic-level category and the exemplars were either associated with the same label, the same nonlinguistic sound, or no auditory input. In sum, labels did have a small effect over nonlinguistic sounds, however, these effects stemmed from sounds overshadowing visual input more than labels, with neither auditory condition exceeding the no auditory baseline.

The goal of current research is to further examine effects of auditory input (including linguistic input) on processing of visual input. In this research, we employed a task that was capable of assessing infants' processing of visual input under different auditory conditions, as well as children's attention to commonalities. In particular, infants in the current study participated in a familiarization task where they were presented with two visual stimuli: one visual stimulus remained the same on every trial (familiar stimulus) and one stimulus (novel stimulus) changed on every trial (see Fantz, 1964; Roder, Bushnell, & Sasseville, 2000 for a similar procedure). The amount of familiarization needed before children demonstrated any systematic looking (i.e., above chance looking to the novel stimulus or familiar stimulus) served as a measure of visual processing speed. By adding auditory input to the task, researchers have used variations of this procedure to investigate early word learning in young children (see Mather & Schafer, 2005; Mather, Schafer, & Houston-Price, 2005). The current study employed a similar procedure to assess processing of visual input under different unimodal and bimodal stimulus presentations.

Understanding how children attend to simultaneously presented auditory and visual input is a necessary condition underlying many cognitive tasks. In particular, understanding attentional factors and attentional learning that occurs in cross-modal processing has implications for not only understanding early word learning, but also for understanding how labels affect categorization and individuation. Based on previous research it was expected that effects of labels, if found, would stem from sounds overshadowing visual input

more than labels, and this effect would stem from familiarity effects as opposed to linguistic effects.

Experiment 1

Method

Participants Forty-five 8-month-olds (23 boys and 22 girls, $M = 249$ days, $Range = 237 - 270$ days) participated in this experiment. Parents' names were collected from local birth announcements, and contact information was obtained through local directories. A majority of infants were Caucasian and had no auditory or visual deficits, as reported by parents. Six infants were not included due to fussiness.

Apparatus Infants were seated on parents' laps approximately 100 cm away from a 152 cm x 127 cm projection screen, which was located approximately 5 cm above the infant's eye level. A Sony DCR-TRV40 camcorder was used to capture infants' fixations and was projected to one of two Dell flat panel monitors in the observation room. An NEC GT2150 LCD projector was mounted on the ceiling approximately 30 cm behind the infant (130 cm away from the projection screen). Two Boston Acoustics 380 speakers were 76 cm apart from each other and mounted in the wall. The speakers and camcorder were concealed by black felt and located directly below the projection screen. Two small lights were located behind the infant to ensure that the room was dimly lit throughout the entire procedure. In an adjacent room, a Dell Dimension 8200 computer with *Presentation* software was used to present stimuli to the infants, as well as to record the onset and offset of infant's visual fixations. Fixations to the visual stimuli were recorded online by pressing one of two buttons on a 10-button USB game pad when infants were looking at the stimuli and releasing the buttons when infants looked away from the stimuli. A second Sony DCR-PC120 camcorder was used to record the video stream of the infant from the monitor indicated above, as well as to record the image of the stimulus presentation on a second Dell flat panel monitor.

Stimuli Infants were familiarized to pairs of visual stimuli and an auditory stimulus. The auditory stimulus consisted of either an unfamiliar sound (a laser sound) or an infant-directed nonsense label ("Look at the dax"). Each auditory stimulus was presented at 65-68 dB for approximately 1200 ms. The visual stimuli consisted of realistic pictorial representations of animals and commonplace objects (e.g., dog, ball, etc.). Each visual stimulus was projected to approximately 36 cm x 36 cm with approximately 100 cm separating the two images.

Procedure The procedure consisted of 24 trials, and each trial was 8000 ms in duration. In each trial, infants were simultaneously presented with two visual stimuli (V1 and V2) and accompanying auditory stimulus (A1). Each successive trial consisted of presenting a new visual stimulus and the old visual stimulus, and children heard the same auditory stimulus throughout familiarization (see Figure 1 for

procedure). As can be seen in Figure 1, A1 and V1 were perfectly correlated, whereas, there was no correlation between A1 with the novel visual stimuli. The left-right location of the novel/familiar stimuli was held constant across training for each subject and counter-balanced between subjects. Fixations were recorded online by an experimenter for all trials.

Figure 1. Overview of Procedure

	Visual pairs	Auditory
Trial 1:	V1 V2	A1
Trial 2:	V1 V3	A1
Trial 3:	V1 V4	A1

Time
↓

Results and Discussion

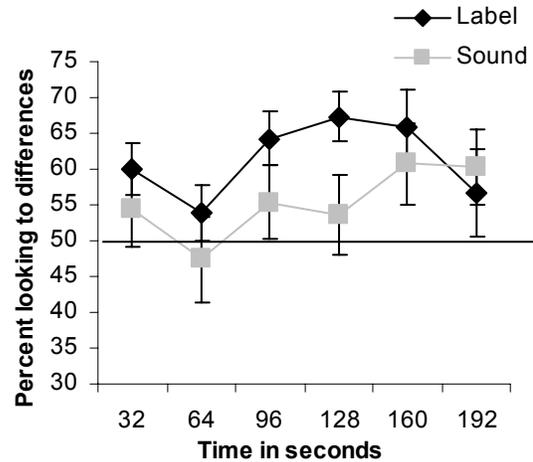
Analysis of test trials focused on infants’ relative looking to commonalities (V1) and differences (V2, V3, etc) across the label and sound conditions. If children map the nonsense label to the correlated visual stimulus (V1) and hearing the same label directs attention to commonalities, then introducing the same label should direct infants’ attention to objects in the environment that share many commonalities with the original referent. In addition, if effects are specific to language than these effects should be found in the label condition but not in the sound condition. However, if effects of labels stem from sounds having stronger overshadowing effects than labels, then infants in the sound condition should require more familiarization before showing any systematic shift in attention compared to children in the sound condition.

Percent looking to the changing visual images (looking to the different stimulus/looking to both stimuli) was calculated on each trial and a mean was averaged across four consecutive trials. A mean greater than 50% reflects an attentional preference to look to differences (novelty preference), whereas a mean below 50% reflects an attentional preference to look to commonalities (i.e., stimulus correlated with the auditory stimulus). As can be seen in Figure 2, hearing the same label across familiarization did not direct infants’ attention to commonalities. In particular, looking was never below 50% in the label condition, and children who heard the same label across familiarization were not more likely to look to commonalities than children in the sound condition.

To determine how the sounds and labels affected processing of the visual input, infants’ preferences were compared to 50%. Infants in the label condition demonstrated a reliable preference after 96 s of familiarization, one-sample $t > 50\%$, $t(24) = 3.79$, $p < .001$, whereas infants in the sound condition never demonstrated a reliable preference, although children had a tendency to look to the different stimuli after

160 s of familiarization, $t > 50\%$, $t(20) = 1.86$, $p < .08$, and after 192 s of familiarization, $t > 50\%$, $t(20) = 1.95$, $p < .07$.

Figure 2. Effects of labels and sounds on processing visual stimuli in Experiment 1



Note: Error bars reflect Standard Errors of the mean.

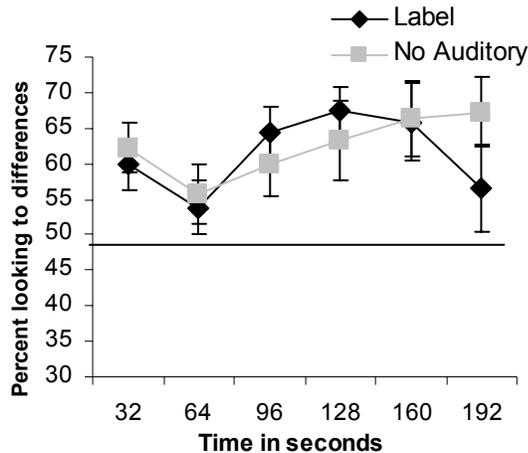
Although hearing the same label did not direct infants’ attention to commonalities, it could be argued that the labels played a special role by facilitating processing of visual input (e.g., Balaban & Waxman, 1997, Waxman & Markow, 1995; Xu, 2002). In other words, it could be argued that hearing the same label was not enough to override children’s preference to look to differences (novelty preference), but exposure to the label did facilitate processing of visual input. At the same time, it is possible that this effect stemmed from the non-speech sounds overshadowing the visual input more than the labels (e.g., Sloutsky & Robinson, 2005; Tobin, Howard, Robinson, & Sloutsky, 2004). To distinguish between these two alternatives, it is important to compare the speed of processing visual stimuli in the label and sound conditions to a no auditory condition.

Twenty-nine additional infants, none of whom participated in the previous experiment, participated in the no-auditory baseline condition. The procedure was identical to the sound and label conditions reported above, however, the auditory stimulus was removed. As can be seen in Figure 3, infants’ looking behaviors became systematic (i.e., different from 50%) in both the label and no auditory conditions at 96 s of familiarization, $ps < .01$, which suggests that the labels did not facilitate processing of visual input relative to their baseline performance in the no auditory condition. Furthermore, across all points of familiarization, there were no differences between infants’ looking in the no auditory condition compared to the label condition, $ps > .1$.

Although these findings suggest that labels had no significant effect on infants’ preferences relative to a no auditory baseline, it is important to note that infants’ attentional preferences in the label condition did drop to

chance at 192 s of familiarization. One possible explanation is that children in this condition simply started responding at chance. However, it is also possible that, after hearing the labels 24 times, children were in the early stages of mapping the label to the correlated visual stimulus.

Figure 3. Effects of labels on processing visual stimuli compared to a no auditory baseline



Note: Error bars reflect Standard Errors of the mean.

In sum, Experiment 1 demonstrated that labels affected infants looking differently than sounds, however, this effect stemmed from sounds overshadowing visual input more than labels. Why did sounds overshadow visual input more than labels? One possibility is that words are different from other types of auditory input. Another possibility is that words represent a familiar class of stimuli, and under repeated presentations, familiar stimuli are less likely to overshadow visual input.

Experiment 2

If differences between the sounds and words in the previous experiment stem from linguistic effects (e.g., words are special) then labels should also have different effects on processing visual input than pre-familiarized sounds. However, if familiarity can account for the previous difference then pre-familiarizing infants to the same nonlinguistic sound used in Experiment 1 should decrease the processing demands needed to encode the auditory stimulus, which should free up the attention resources that are needed to process the visual stimulus. From this perspective, pre-familiarized sounds and words should have comparable effects.

Method

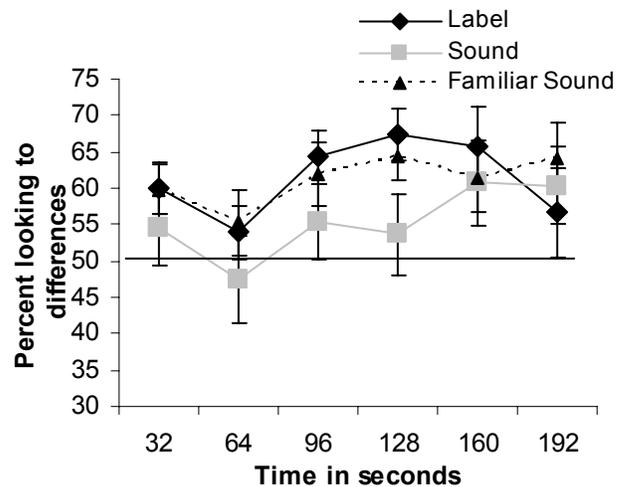
Participants Nineteen 8-month-olds (9 boys and 10 girls, $M = 249$ days, $Range = 212 - 274$ days). Recruitment procedures and demographics were identical to Experiment 1. Two infants were not included due to fussiness.

Stimuli and Procedure The procedure was similar to the sound condition of Experiment 1, except that children heard the nonlinguistic sound 20 times prior to participating in the experiment proper (pre-familiarization phase). The laser sound was not associated with any visual images during pre-familiarization, and children were given a short break prior to testing.

Results and Discussion

Percent looking to the changing visual images (i.e., looking to differences) was calculated on each trial and a mean was averaged across 4 consecutive trials. As can be seen in Figure 4, children who heard pre-familiarized sounds shifted their attention to differences after 96 s, $t > 50\%$, $t(18) = 2.69$, $p < .05$, which was comparable to children who heard the labels. Furthermore, there was no point across familiarization where infants' looking in the label condition (Experiment 1) differed from infants' looking in the pre-familiarized sound condition (Experiment 2), $ps > .1$.

Figure 4. Effects of familiar sounds on visual processing



Note: Error bars reflect Standard Errors of the mean.

General Discussion

The results of the current study reveal several important findings. First, children who heard the same non-speech sound across familiarization responded differently to the visual images than children who heard the same label. However, these effects stemmed from non-speech sounds overshadowing visual input more than labels. Second, there was no evidence suggesting that hearing the same label directed infants' attention to commonalities. In fact, infants who heard the same label (e.g., "Look at the dax") were actually more likely to direct their attention away from the correlated visual stimulus. The current study expands previous research investigating mechanisms underlying the effects of labels on cognitive development.

It has been demonstrated that hearing the same label associated with different objects (e.g., Balaban & Waxman, 1997), and hearing different labels associated with different objects facilitates individuating object kinds (e.g., Xu, 2002). Furthermore, it has been argued that the mechanisms underlying these effects reflect the notion that children initially have broad assumptions that words but not sounds highlight categories and hearing the same label directs attention to commonalities and hearing different labels directs attention to differences (Waxman, 2003). The finding that both familiar sounds and labels have similar effects on infants' attention questions whether young infants already understand that notion that words refer to categories.

However, effects of labels on cognitive tasks can occur in several ways. For example, some auditory stimuli can hinder rather than facilitate processing of corresponding visual input, and these effects can affect object recognition and categorization tasks (Robinson & Sloutsky, 2004; Tobin, Howard, Robinson, & Sloutsky, 2004). Therefore, it is not only important to investigate categorization and individuation behaviors across different auditory stimulus conditions, but also to make specific predictions about the mechanism(s) underlying this ability. For example, if labels but not sounds direct attention to commonalities then children should be faster at noticing commonalities between entities, thus, demonstrating faster habituation rates when visual images are associated with the same label (see Waxman & Markow, 1995 for a similar claim). To date, there is very little evidence supporting this claim using typical categorization tasks (e.g., Balaban & Waxman, 1997; Fulkerson & Haaf, 2003; Tobin, Howard, Robinson, & Sloutsky, 2004). While the current task did find some support for this claim using a more sensitive task where children were given 192 s to process a single stimulus (V1), it is important to note that this finding was not specific to language (Experiment 2).

The current study has implications beyond cross-modal processing in infancy. In particular, attentional factors and attentional learning in cross-modal processing underlie many cognitive tasks such as word learning and how labels affect categorization, individuation, and induction. The current study, in conjunction with Napolitano and Sloutsky (2004) and Robinson and Sloutsky (2004), question whether children really understand that words refer to categories. Rather, many linguistic effects often attenuate when labels are compared with familiar nonlinguistic stimuli. Furthermore, by focusing on children's attention to simultaneously presented auditory and visual input more generally, Napolitano and Sloutsky (2004) and Robinson and Sloutsky (2004), have demonstrated that even 4-year-olds have difficulty selectively deploying their attention to a specific auditory or visual component of a compound stimulus. Without such attentional control, it is unlikely that children can deliberately use labels, even if they do understand their conceptual importance.

Acknowledgments

This research has been supported by grants from the National Science Foundation (REC # 0208103 and BCS # 0078945) to Vladimir M. Sloutsky.

References

- Balaban, M.T., & Waxman, S.R. (1997). Do words facilitate object categorization in 9-month-old infants? *Journal of Experimental Child Psychology*, *64*, 3-26.
- Fantz, R.L. (1964). Visual experience in infants: Decreased attention to familiar patterns relative to novel ones. *Science*, *46*, 668-670.
- Fulkerson, A.L., & Haaf, R.A. (2003). The influence of labels, non-labeling sounds, and source of auditory input on 9- and 15-month-olds' object categorization. *Infancy*, *4*, 349-369.
- Mather, E. & Schafer, G. (2005, April). *Familiarity and novelty preferences for visual stimuli in the second year of life: Initial findings and new directions*. Poster presented at the Biennial meeting of the Society for Research in Child Development, Atlanta, GA, April 2005.
- Mather, E., Schafer, G., & Houston-Price, C. (2005). *Object-label covariation – A cue for The acquisition of nouns?*. Manuscript submitted for publication.
- Napolitano, A. C., & Sloutsky, V. M. (2004). Is a Picture Worth a Thousand Words? The Flexible Nature of Modality Dominance in Young Children. *Child Development*, *75*, 1850-1870.
- Robinson, C.W. & Sloutsky, V.M. (2004). Auditory dominance and its change in the course of development. *Child Development*, *75*, 1387-1401.
- Roder, B.J., Bushnell, E.W., & Sasseville, A.M. (2000). Infants' preferences for familiarity and novelty during the course of visual processing. *Infancy*, *1*(4), 491-507.
- Sloutsky, V. M., & Napolitano, A. (2003). Is a picture worth a thousand words? Preference for auditory modality in young children. *Child Development*, *74*, 822-833
- Sloutsky, V.M., & Robinson, C.W. (2005). *The role of words and sounds in visual processing: From overshadowing to attentional tuning*. Manuscript submitted for publication.
- Tobin, L., Howard, E., Robinson, C.W., & Sloutsky, V.M. (2004, May) *The effect of non-speech sounds and labels on categorization*. Poster session presented at the Biennial International Conference for Infant Studies, Chicago, IL.
- Waxman, S. R. (2003). Links between object categorization and naming: Origins and emergence in human infants. In D. H. Rakison & L. M. Oakes (Eds.), *Early category and concept development: Making sense of the blooming, buzzing confusion* (pp. 213-241). London, UK: Oxford University Press.
- Waxman, S. R., & Markow, D. B. (1995). Words as invitations to form categories: Evidence from 12- 13-month-old infants. *Cognitive Psychology*, *29*, 257-302.
- Xu, F. (2002). The role of language in acquiring object kind concepts in infancy. *Cognition*, *85*, 223-250.