

Linguistic Labels and Categorization in Infancy: Do Labels Facilitate or Hinder?

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Although it is generally accepted that labels facilitate categorization in infancy, recent evidence suggests that infants and young children are more likely to process visual input when presented in isolation than when paired with nonlinguistic sounds or linguistic labels. These findings suggest that auditory input (when compared to a no-auditory baseline) may hinder rather than facilitate categorization. This study assessed 8-month-olds' ($n = 191$) and 12-month-olds' ($n = 81$) abilities to form categories when images were paired with nonlinguistic sounds, linguistic labels, and when presented in isolation. Overall, infants accumulated more looking when visual stimuli were accompanied by sounds or labels; however, infants were more likely to categorize when the visual images were presented without an auditory stimulus.

The ability to form categories by treating discriminable stimuli as members of an equivalence class is an important component of human cognition (see Murphy, 2002, for a review). This ability appears early in development, with very young infants ably forming basic-level as well as superordinate or global categories (Behl-Chadha, 1996; Mandler & McDonough, 1993; McDonough & Mandler, 1998; Oakes, Madole, & Cohen, 1991; Quinn, Eimas, & Rosenkrantz, 1993; Younger & Furrer, 2003).

Even though infants are capable of forming categories at an early age, it has frequently been argued that linguistic input can further facilitate category learning at the earliest stages of word learning (Balaban & Waxman, 1997; Fulkerson, Waxman, & Seymour, 2006; Waxman & Booth, 2003; Waxman & Markow, 1995). Ac-

cording to one position, linguistic input facilitates categorization because even prelinguistic infants are said to have general assumptions that words but not other types of auditory stimuli refer to categories (e.g., Balaban & Waxman, 1997; Waxman & Booth, 2003; Xu, 2002). Thus, under this proposal, “infants embark on the task of word learning equipped with a broad, universally shared expectation, linking words to commonalities among objects” (Waxman, 2003, p. 220).

There is much evidence consistent with this view. First, linguistic labels facilitate categorization above and beyond other types of nonlinguistic, auditory input (Balaban & Waxman, 1997; Fulkerson & Haaf, 2003; Fulkerson et al., 2006; but see Roberts, 1995; Roberts & Jacob, 1991, for diverging evidence). In particular, in these studies young infants were more likely to form categories when different exemplars of the to-be-formed categories were accompanied by the same linguistic input (e.g., “a rabbit”) than when the exemplars were accompanied by the same nonlinguistic input (e.g., sine wave, short melody, etc.). Second, effects of linguistic input were shown for a wide range of categories, including basic-level as well as superordinate categories (Balaban & Waxman, 1997; Fulkerson & Haaf, 2003; Waxman & Booth, 2003; Waxman & Markow, 1995). Finally, effects of linguistic input have been reported to affect performance on a variety of cognitive tasks. For example, there is evidence that when two stimuli are accompanied by the same label, infants are more likely to generalize properties from one entity to the other (Graham, Kilbreath, & Welder, 2004; Welder & Graham, 2001). In addition, when two different stimuli are accompanied by different labels, infants are more likely to separate or individuate these stimuli (Xu, 2002; Xu, Cote, & Baker, 2005).

This support notwithstanding, there are challenges to the idea that prelinguistic infants assume that words refer to categories. First, young infants often have difficulty binding words and objects (e.g., Casasola & Cohen, 2000; Gogate & Bahrick, 1998; Hollich, Hirsh-Pasek, & Golinkoff, 2000; Mervis & Bertrand, 1995; Werker, Cohen, Lloyd, Casasola, & Stager, 1998), which casts doubt on whether infants can quickly learn more abstract word–category relations. Second, infants and young children are often more likely to process visual input when presented in isolation than when paired with an auditory stimulus (Napolitano & Sloutsky, 2004; Robinson, Howard, & Sloutsky, 2005; Robinson & Sloutsky, 2004a, 2004b; Sloutsky & Napolitano, 2003). These findings suggest that infants could be more likely to form perceptual categories in the absence of auditory stimuli, rather than in the presence of auditory stimuli. Furthermore, given that young infants can detect correlations among features and ably learn categories when the to-be-categorized stimuli are presented without auditory input (e.g., Quinn et al., 1993; Younger & Cohen, 1983), it is uncertain whether linguistic labels help infants learn categories that would go undetected in the absence of auditory input.

If these challenges to the idea that labels facilitate categorization are taken seriously, it is important to explain why prelinguistic infants exhibit (at least under some conditions) better categorization performance when stimuli are accompa-

nied by linguistic input than when they are accompanied by nonlinguistic sounds. We propose that the effects of labels and sounds on categorization may stem from the allocation of attention in the course of cross-modal processing. In particular, studies focusing on cross-modal processing have demonstrated that under many conditions auditory input overshadows (or attenuates processing of) corresponding visual input (Lewkowicz, 1988a, 1988b; Napolitano & Sloutsky, 2004; Robinson et al., 2005; Robinson & Sloutsky, 2004a, 2004b; Sloutsky & Napolitano, 2003). For example, in Robinson and Sloutsky's (2004a) study, 8-, 12-, and 16-month-olds were familiarized to an auditory-visual compound stimulus (i.e., nonlinguistic sound and geometric shape). After familiarization, participants were presented with one of the four test items: (a) old target (which was identical to the familiarization item), (b) an item that had the auditory component changed, (c) an item that had the visual component changed, or (d) an item that had both auditory and visual components changed. Infants in this study encoded the auditory stimulus, as indicated by increased looking when the auditory component changed, but often failed to encode the visual stimulus. This finding is worth noting given that infants in control studies ably processed the same visual stimuli when presented without the auditory stimulus. Therefore, compared to a no-auditory condition, these findings demonstrate that nonlinguistic sounds hindered encoding of a corresponding visual input (Robinson & Sloutsky, 2004a, 2004b) and slowed up visual processing, as indicated by the amount of familiarization needed before infants demonstrated a reliable novelty preference (Robinson et al., 2005).

These auditory overshadowing effects are not limited to nonlinguistic sounds: Labels can also exhibit overshadowing effects, which, however, may be less pronounced than those of nonlinguistic sounds (Robinson et al., 2005; Robinson & Sloutsky, 2004b). In particular, when given ample time to process bimodal stimuli, familiar auditory stimuli (human speech or prefamiliarized nonlinguistic sounds) are less likely to interfere with visual processing than unfamiliar auditory stimuli. Therefore, it is possible that the observed effects of labels eliciting better categorization performance than sounds could stem from nonlinguistic sounds overshadowing or interfering with visual processing more than labels.

In short, effects of labels may either stem from labels facilitating categorization or, as predicted by the overshadowing hypothesis, from labels attenuating visual processing less than nonlinguistic sounds. The only way to tease these two explanations apart is to compare categorization in the label and nonlinguistic sound conditions to categorization in a no-auditory or silent condition. The few studies that have made this comparison have yielded mixed results (Fulkerson & Haaf, 2003; Roberts, 1995; Roberts & Jacob, 1991), thus, it is still open for debate whether labels help infants form categories that would go undetected in the absence of any auditory stimulus.

The primary goal of this study is to determine if labels facilitate categorization above a no-auditory condition (i.e., silent condition) at the onset of word learning.

To achieve this goal, we presented infants with a categorization task and compared their performance in the label, sound, and silent conditions. In what follows, we present two experiments investigating 8- and 12-month-olds' categorization performance under these different familiarization conditions. Participants were familiarized to a basic-level category (e.g., a cat) in one of the three conditions: (a) visual stimuli were accompanied by linguistic labels, (b) visual stimuli were accompanied by nonlinguistic sounds, or (c) visual stimuli were not accompanied by auditory stimuli (i.e., silent condition). After familiarization, infants were presented with two test trials, each consisting of a novel in-category exemplar (e.g., a new cat) and a novel out-of-category exemplar (e.g., a novel bear) shown simultaneously. Categorization was measured by the percentage looking to the out-of-category exemplar after familiarization compared to infants' initial preference (i.e., percentage looking to the out-of-category exemplar without being familiarized to one of the categories).

If labels facilitate categorization, then infants should be more likely to categorize in the label condition than in the sound and silent conditions. However, if auditory input overshadows visual input early in development, then infants should be more likely to form a category in the silent condition than in the label and sound conditions. Based on the auditory overshadowing effects reported previously (Robinson & Sloutsky, 2004a, 2004b) and young infants' difficulty in forming word-object relations (e.g., Werker et al., 1998), we expected that nonlinguistic sounds and possibly labels would overshadow corresponding visual input, thus hindering categorization compared to a silent condition.

EXPERIMENT 1

Method

Participants. Ninety-one 8-month-olds (39 boys and 52 girls, $M = 244$ days, range = 229–267 days) and 71 12-month-olds (45 boys and 26 girls, $M = 373$ days, range = 357–422 days) participated in this experiment. Parents' names were collected from local birth announcements, and contact information was obtained through local directories. All participants were full-term with no auditory or visual deficits, as reported by parents. The majority of infants were White from middle- to upper middle-class suburbs of Columbus, Ohio. Data provided by 4 infants were excluded due to fussiness and 1 infant was excluded for not looking at a single test trial.

Apparatus. Infants were seated on parents' laps approximately 100 cm away from a 152 cm \times 127 cm projection screen. A 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, which were 76 cm apart from each other and mounted in the wall, were located at the infant's eye level. 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 infants' visual fixations. Fixations were recorded online by pressing a button on a 10-button USB game pad when infants were looking at the stimulus. Two video streams (stream of stimulus presentation and stream of infants' fixations) were projected onto two Dell flat-panel monitors in an adjacent room, and a Sony DCR-PC120 camcorder recorded both video streams. This split-screen recording was used to establish interrater reliability.

A random sample of 30% of the infants was coded offline. Offline coders concealed the half of the split-screen associated with the stimulus presentation, thus blinding themselves to the auditory and visual information presented to infants. Offline coders then coded infants' visual fixations at a resolution of 30 frames per second. Reliabilities for online and offline coders were calculated for each infant and averaged across all reported experiments ($n = 84$), average $r = .94$.

Materials and Design. The auditory stimuli consisted of a nonlinguistic sound (i.e., laser sound) and an infant-directed linguistic label (i.e., "a cat"). Both auditory stimuli were dynamic (i.e., changing in pitch and amplitude), and they were each presented at 65 dB to 68 dB for 1,000 msec. The visual stimuli consisted of 10 familiarization stimuli (10 different cats) and 4 test stimuli (2 novel cats and 2 bears). All visual stimuli were realistic representations of cats and bears and were presented at approximately 36 cm \times 36 cm in size (see Appendix for visual stimuli).

The design included two between-subject factors: age (8-month-olds vs. 12-month-olds) and stimulus condition (sounds, labels, and silent). Forty-three infants (22 8-month-olds and 21 12-month-olds) were presented with nonlinguistic sounds during familiarization, 44 infants (26 8-month-olds and 18 12-month-olds) were presented with linguistic labels during familiarization, and 46 infants (28 8-month-olds and 18 12-month-olds) did not receive any auditory input during familiarization (i.e., silent condition). An additional 29 infants (15 8-month-olds and 14 12-month-olds) were included to establish initial preferences for the testing stimuli (i.e., novel cats and novel bears). These infants saw the same testing stimuli as the infants in the sound, label, and silent conditions; however, these infants were not familiarized to the cat category prior to testing.

Procedure. Infants sat on their parents' laps approximately 100 cm away from a projection screen. Parents were instructed to not interact, point, or label any of the pictures. A colorful picture of a baby playing with several different toys was projected on the screen to keep infants' attention prior to the experiment. When infants and parents were ready to begin, an experimenter started the experiment by

pressing a button on the 10-button USB game pad. At this time, the picture of the baby disappeared and infants were presented with 10 familiarization trials. Each familiarization trial consisted of a different cat with a white background that appeared for 8,000 msec. Sounds and labels were presented at the onset of the visual stimulus and lasted for 1,000 msec. Thus, in contrast to previous research investigating auditory dominance in infancy (e.g., Robinson & Sloutsky, 2004a, 2004b), the visual stimuli in this study were presented for an additional 7,000 msec after the offset of the auditory stimulus. Infants heard no auditory input in the silent condition. After each familiarization trial, the cat disappeared and the projection screen blackened for 1,000 msec prior to the next familiarization stimulus.

After familiarization, infants were presented with two test trials. Each test trial consisted of a novel in-category exemplar (cat) and a novel out-of-category exemplar (bear), presented simultaneously. Test stimuli were presented to the left and right sides of the projection screen and approximately 64 cm apart from each other. As with familiarization trials, the duration of each test trial lasted 8,000 msec. No auditory input was presented at test. The orders of familiarization and of test trials were randomized and left–right location of test stimuli were counterbalanced within participants. Fixation durations were recorded online during familiarization and test trials.

Results and Discussion

Analyses focused on accumulated looking during the familiarization phase and on the percentage looking to the novel category at test compared to infants' initial preference. A 2 (age: 8 months vs. 12 months) \times 3 (stimulus condition: sound, label, and silent) analysis of variance (ANOVA) with age and stimulus condition as between-subject factors revealed a main effect of stimulus condition, $F(2, 127) = 22.80, p < .001$ ($\eta^2 = .26$). Across the 80-sec familiarization phase, infants accumulated more looking when the stimuli were accompanied by the nonlinguistic sound ($M = 61.04$ sec, $SE = 2.01$ sec) and the linguistic label ($M = 60.40$ sec, $SE = 1.59$ sec) than when the same visual stimuli were presented in the silent condition ($M = 44.25$ sec, $SE = 2.12$ sec), $t_s > 5.74, p < .001$. Furthermore, accumulated looking during familiarization did not differ between the label and sound conditions, $t(85) = 0.25, p = .80$, which suggests that the labels and sounds had comparable effects on increasing infants' attention. This analysis also revealed a main effect of age, $F(1, 127) = 5.54, p < .05$ ($\eta^2 = .04$), with 12-month-olds ($M = 58.52$ sec, $SE = 1.76$ sec) accumulating more looking during familiarization than 8-month-olds ($M = 52.40$ sec, $SE = 1.79$ sec).

To examine whether labels facilitated categorization, a preference novelty score was calculated for each test trial: accumulated looking time to the out-of-category exemplar (i.e., bear) divided by the overall looking time for both the in-category and out-of-category stimuli. A mean novelty score was then averaged across the two test trials (see Table 1 for percentages broken up by age and stimulus condi-

TABLE 1
Percent Looking to Novel Category (i.e., Bear) Across Age and Stimulus
Condition in Experiment 1

Age	Stimulus Condition			
	Initial Preference	Silent	Label	Sound
8 months	43.98	50.09	45.18	45.78
12 months	44.08	57.45*	48.62	42.91

* $p < .05$, different from initial preference.

tion). Difference scores were then calculated by subtracting the percentage looking to the novel category before familiarization (i.e., infants' initial preference) from the percentage looking to the novel category at test. If labels facilitate categorization, then infants should increase looking to the novel category in the label condition compared to infants' initial preference (i.e., difference scores should be greater than 0), and this increase in looking should exceed the sound and silent conditions. However, if labels and sounds overshadow or interfere with visual processing, then infants should be more likely to categorize in the silent condition than in the label and sound conditions.

As can be seen in Figure 1, 12-month-olds' looking to the novel category differed across the stimulus conditions, one-way ANOVA with stimulus condition as a between-subject factor, $F(2, 54) = 7.28$, $p < .005$ ($\eta_p^2 = .21$). In particular, 12-month-olds in the silent condition ($M = 13.80\%$, $SE = 3.41\%$) accumulated more looking to the novel category compared to infants' initial preference, difference score > 0 , $t(17) = 4.05$, $p < .001$, whereas looking to the novel category in the label ($M = 4.53\%$, $SE = 3.18\%$) and sound conditions ($M = -1.17\%$, $SE = 1.88\%$) did not differ from 0, $ts < 1.43$, $p > .17$. Twelve-month-olds also looked longer to the novel category in the silent condition compared to the sound condition, $t(37) = 4.00$, $p < .001$, or to the label condition, $t(34) = 1.99$, $p = .055$. Furthermore, similar to previous reports (e.g., Balaban & Waxman, 1997), these infants also looked longer to the novel category in the label condition than in the sound condition, $t(37) = 1.60$, $p < .06$ (one-tailed). In contrast to the 12-month-olds, 8-month-olds' looking to the novel category did not differ across the stimulus conditions, $F(2, 73) = 0.92$, $p = .40$ ($\eta_p^2 = .03$)¹. However, these infants were starting to show evidence of categorizing in the silent condition: 8-month-olds in the silent condition ($M = 6.11\%$, $SE = 3.41\%$), difference score > 0 , $t(27) = 1.79$, $p = .084$.

¹A follow-up experiment with 10 8-month-olds (5 boys and 5 girls, $M = 247$ days, range = 237–261 days), none of whom participated in Experiment 1, indicated that 8-month-olds ably discriminated the individual cats and bears that were presented during the testing phase of Experiment 1, $t(9) = 3.87$, $p < .005$.

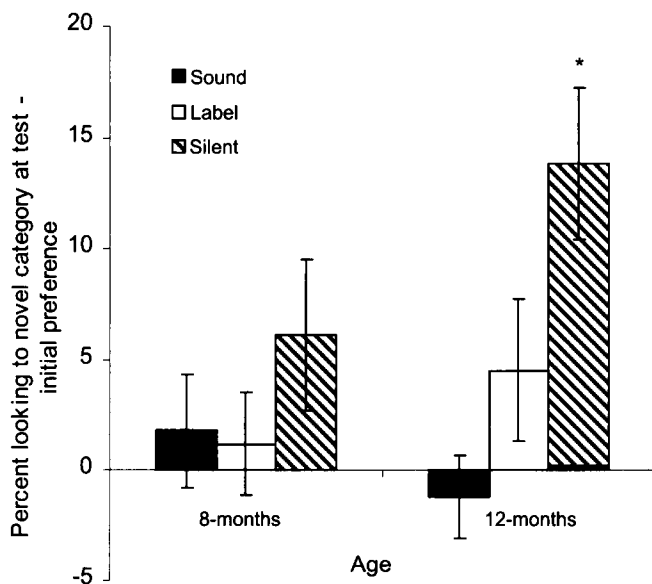


FIGURE 1 Difference scores across age and stimulus condition in Experiment 1. Error bars represent standard errors of the mean. *Note.* * $p < .001$, different from 0.

Experiment 1 demonstrates that 12-month-olds were more likely to categorize in the silent condition, however, it is also possible that 12-month-olds simply could not discriminate the familiarization cats from the novel testing cats in the silent condition. Thus, a control experiment was conducted to ensure that 12-month-olds could in fact discriminate the individual cats when presented in isolation. In the control experiment, 10 12-month-olds (6 boys and 4 girls, $M = 371$ days, range = 356–406 days), none of whom participated in the previous experiment, were familiarized to one of the familiarization stimuli (i.e., a single cat randomly drawn from the pool of familiarization stimuli) and were then presented with two test trials. Each test trial was constructed by pairing the familiarized cat with one of the novel testing cats. No auditory input was provided in the control experiment. If infants can discriminate the familiarization and testing cats then infants' relative looking to the novel testing cats should increase after familiarization (i.e., test phase) compared to their looking to the same novel cats before familiarization (i.e., initial preference phase). In contrast to the experiment proper, the control experiment had the following three phases that were manipulated within subjects: initial preference \rightarrow familiarization \rightarrow test. Difference scores were calculated (i.e., looking to novel stimuli at test – initial preference) and were compared to 0. Twelve-month-olds increased looking to the novel stimuli at test ($M = 8.48\%$, $SE = 3.79\%$), difference score > 0 , $t(9) = 2.24$, $p < .05$. This finding suggests that 12-month-olds'

increased looking to the novel category in the silent condition cannot be accounted for by an inability to discriminate the individual cats.

In summary, even though infants accumulated significantly more looking to the visual stimuli in the label and sound conditions, infants were more likely to form basic-level categories in the silent condition. These findings are consistent with previous research investigating auditory dominance effects in infants and young children (Napolitano & Sloutsky, 2004; Robinson & Sloutsky, 2004a, 2004b; Sloutsky & Napolitano, 2003), and expand on previous research in three ways. First, Experiment 1 demonstrates that under some conditions auditory stimuli may also hinder category learning: Recall that previous research on overshadowing only examined effects of auditory input on recognition of individual visual stimuli. Second, whereas previous research has examined infants' encoding of three-shape patterns (Robinson & Sloutsky, 2004a, 2004b), this study demonstrates that these auditory effects can be generalized to realistic pictures of animals. Third, these auditory effects are not contingent on the synchronous presentation of auditory and visual stimuli. Recall that the visual stimuli in Experiment 1 were presented for an additional 7,000 msec after the offset of the auditory stimulus, whereas the auditory and visual stimuli were presented for the same duration in Robinson and Sloutsky's (2004a, 2004b) studies. Thus, a single exposure to an auditory stimulus (e.g., this experiment) and repeated exposures to an auditory stimulus (e.g., Robinson & Sloutsky, 2004a, 2004b) both interfered with processing of a corresponding visual stimulus, thus hindering recognition and categorization.

EXPERIMENT 2

Although Experiment 1 demonstrated that sounds and labels hindered category learning at 12 months of age, the results were less clear for 8-month-olds. Experiment 2 was designed to further examine how auditory input affects 8-month-olds' category learning under more sensitive testing conditions, as well as to examine recognition and categorization after differing amounts of familiarization. Based on the overshadowing hypothesis, it was expected that infants' recognition and categorization performance would be hindered by the presence of an auditory stimulus.

Method

Participants and apparatus. The sample consisted of 80 8-month-olds (46 boys and 34 girls, $M = 252$ days, range = 238–276 days). Recruitment procedures and demographic characteristics were identical to those in Experiment 1. Data provided by 13 infants were excluded due to fussiness, and an additional 6 infants were excluded because they did not contribute enough looking across test trials to

calculate a mean. The apparatus used in Experiment 2 was identical to the apparatus reported in Experiment 1.

Stimuli. Two changes were made to the auditory stimuli in this experiment. First, given the effects of a referential context on the formation of word–category and sound–category associations (e.g., Campbell & Namy, 2003; Namy & Waxman, 2000), 8-month-olds in this experiment heard “Look at the X,” as opposed to hearing the labels presented in isolation. Second, to ensure that facilitative effects of labels (if such effects are found) stem from linguistic input per se, and not from familiarity with the auditory input (cf. Robinson & Sloutsky, 2004b), this experiment used a nonsense label (e.g., “fep”) instead of the real labels. The introduction of novel words also required the introduction of unfamiliar items to be denoted by these novel words. Details of visual stimuli are presented later.

This experiment used the categories of turtle, fish, and frog because these categories are less likely to be known to young infants than the category of cat (cf. Fenson et al., 1994). In this experiment infants were familiarized to turtles and tested on either fish or frogs (see Appendix for visual stimuli). Using the same procedure as reported in the control experiment of Experiment 1, infants’ discrimination of the individual turtles was tested. Ten 8-month-olds (6 boys and 4 girls, $M = 250$ days, range = 231–282 days), none of whom participated in Experiment 2, discriminated the familiarization turtles from the testing turtles, $t(9) = 2.27$, $p < .05$.

Several additional changes were made to the stimulus presentation to make the task easier for infants. First, to reduce task demands, the size of the familiarization category was reduced: Participants in this experiment were only familiarized to 4 exemplars, as opposed to 10 exemplars in the previous experiment. Second, to encourage comparison between the familiarization stimuli (e.g., Namy & Gentner, 1999, 2002) and to reduce the differences between familiarization and test trials, stimuli were presented in pairs during both the familiarization and testing phases (see Oakes & Ribar, 2005, for additional discussion). Recall that in Experiment 1, stimuli were presented individually during familiarization and in pairs at testing.

Procedure. Similar to Experiment 1, infants were randomly assigned to a label condition ($n = 27$), a nonlinguistic sound condition ($n = 25$), or a silent condition ($n = 28$). Approximately half of the infants were familiarized to turtles and tested on frogs and the remaining infants were familiarized to turtles and tested on fish.

Several changes were made to the procedure to make the task more sensitive than the one used in Experiment 1. First, as in the control experiments, we assessed each infant’s initial preference before the familiarization phase. Recall that in Experiment 1 infants’ initial preferences were assessed as a between-subject factor. Second, this experiment introduced category contrast trials prior to assessing categorization, in which participants were presented with a familiarization stimulus

paired with a novel stimulus (cf. Eimas, Quinn, & Cowan, 1994). Thus, in contrast to the control experiments, the current task structure was initial preference → familiarization → contrast → test. These contrast trials served several functions and are discussed in more detail later. Finally, in contrast to Experiment 1, categorization performance was assessed after differing amounts of familiarization (see Figure 2 for an overview of the procedure). The details of each phase are presented next.

The initial preference phase consisted of four trials. Each initial preference trial consisted of two test stimuli (e.g., turtle paired with fish) that were presented simultaneously for 8,000 msec. Each stimulus pair was presented twice to counterbalance the left–right location of the stimuli. No auditory input was provided during this phase. A percentage looking to the novel category (i.e., fish or frog) was assessed on each trial and a mean was calculated across the four initial preference trials. Thus, each infant provided saliency information for the testing stimuli prior to the familiarization phase.

During the familiarization phase, infants were presented with eight familiarization trials. Each familiarization trial consisted of two turtles appearing simultaneously for 8,000 msec. Two different pairs of turtles (four different exemplars) appeared throughout familiarization, and each pair was presented four times. During familiarization infants heard, “Look at the feps,” a laser sound, or nothing in

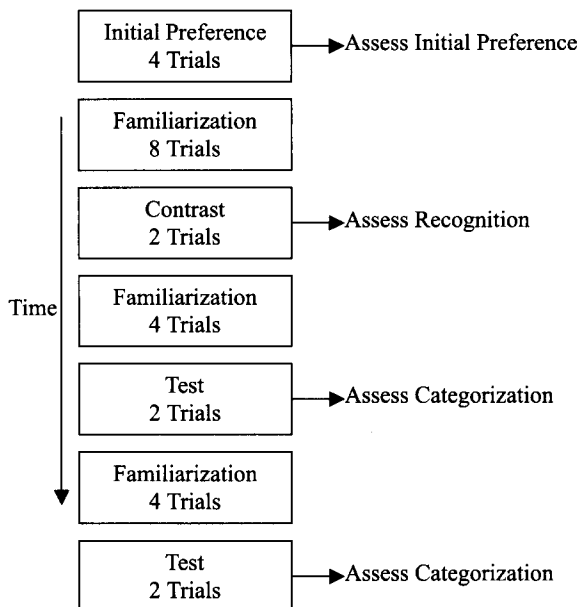


FIGURE 2 Overview of Experiment 2.

the label, sound, and silent conditions, respectively. As in Experiment 1, the auditory stimulus was only presented once and at the onset of each familiarization trial. Looking was recorded on each familiarization trial by summing fixation durations to both images.

During the contrast phase, two of the four familiarization stimuli were paired with novel exemplars from a novel category. Furthermore, the novel category that was presented during the contrast phase differed from the novel category presented during initial preference and test phases. For example, for those infants familiarized to turtles and tested on frogs, each contrast trial for these infants would have consisted of a familiarized turtle paired with a novel fish. Infants familiarized to turtles and tested on fish were presented with familiarized turtles and novel frogs during the contrast phase. There were two contrast trials. Each contrast trial lasted 8,000 msec, and no auditory input was provided.

The contrast phase served three functions. First, the contrast phase should make the task easier for young infants: Introducing a category contrast after infants are familiarized to a category often facilitates category responding (cf. Eimas et al., 1994). Second, because the familiar stimuli presented during the contrast phase were identical to the stimuli presented during the familiarization phase, the contrast trials also served as a measure of recognition memory. Third, contrast trials were introduced to ensure that chance performance in the label condition, if found, does not stem from half of the infants demonstrating a novelty preference and half of the infants demonstrating a familiarity preference (i.e., contrast trials were an independent measure to separate novelty or familiarity responders prior to assessing categorization).

During the test phase, infants were presented with four test trials. Test trials were identical to initial preference trials, and categorization was assessed by comparing infants' looking to the novel category on test trials with their looking to the same stimuli on initial preference trials. As can be seen in Figure 2, categorization was assessed after 12 and 16 familiarization trials. Recall that in Experiment 1 categorization was assessed after 10 familiarization trials.

Results and Discussion

Analyses focused on accumulated looking during familiarization and on recognition and categorization performance. A one-way ANOVA with stimulus condition (i.e., sounds, labels, and silent) as a between-subject factor revealed a main effect of stimulus condition, $F(2, 77) = 12.09$, $p < .001$ ($\eta_p^2 = .24$). Across the 64-sec familiarization phase (i.e., first 8 familiarization trials), infants accumulated more looking when the stimuli were accompanied by the nonlinguistic sound ($M = 36.89$ sec, $SE = 2.17$ sec) and the linguistic label ($M = 34.34$ sec, $SE = 1.92$ sec) than when the same stimuli were presented in the silent condition ($M = 23.69$ sec, $SE = 2.00$ sec), $t_s > 3.83$, $p < .001$. In addition, accumulated looking

did not differ between the label and sound conditions, $t(50) = 0.88$, $p = .38$, which suggests that the labels and sounds had comparable effects on increasing infants' attention.

Difference scores were calculated by subtracting infants' initial preference from looking to the novel category after familiarization (see Table 2 for percentages broken up by phase and stimulus condition). A 2 (phase: contrast vs. test) \times 3 (stimulus condition: sound, label, and silent) ANOVA with phase as a repeated measure revealed a main effect of stimulus condition, $F(2, 77) = 3.20$, $p < .05$ ($\eta_p^2 = .08$). Collapsed across phase, infants accumulated more looking to the novel category in the silent condition ($M = 9.32\%$, $SE = 3.46\%$) than in the sound condition ($M = -1.62\%$, $SE = 2.90\%$), $t(51) = 2.39$, $p < .05$. Furthermore, as can be seen in Figure 3, only infants in the silent condition increased looking to the novel category on contrast trials ($M = 9.30\%$, $SE = 4.07\%$) or on test trials ($M = 9.33\%$, $SE = 4.26\%$), difference score > 0 , $ts > 2.19$, $ps < .05$. This suggests that only infants in the silent condition recognized the individual familiarization stimuli and discriminated them from novel stimuli (i.e., accurate recognition), and treated the novel stimuli from the familiar category as members of the same category (i.e., accurate categorization).

To ascertain that the poor categorization performance exhibited in the label condition did not stem from some infants demonstrating a novelty preference and some infants demonstrating a familiarity preference, we only included those infants who were already showing a novelty preference after eight familiarization trials (i.e., greater than 50% looking to the novel stimuli on contrast trials). Even when including only novelty responders in the following analysis, infants looking at test ($M = 0.81\%$, $SE = 6.04\%$) did not differ from their initial preference, difference score > 0 , $t(13) = 0.13$, $p = .90$.

TABLE 2
Percent Looking to Novel Category (i.e., Fish or Frog) Across Time
and Stimulus Condition in Experiment 2

Stimulus Condition	Phase			
	Initial Preference	Contrast	Test Phase	
	No Familiarization	After 8 Familiarization Trials	After 12 Familiarization Trials	After 16 Familiarization Trials
	Trials 1-4	Trials 1-2	Trials 1-2	Trials 3-4
Silent	45.39	54.70*	52.21	59.27*
Label	46.12	49.37	48.72	53.14
Sound	50.75	48.78	45.88	53.13

* $p < .05$, different from initial preference.

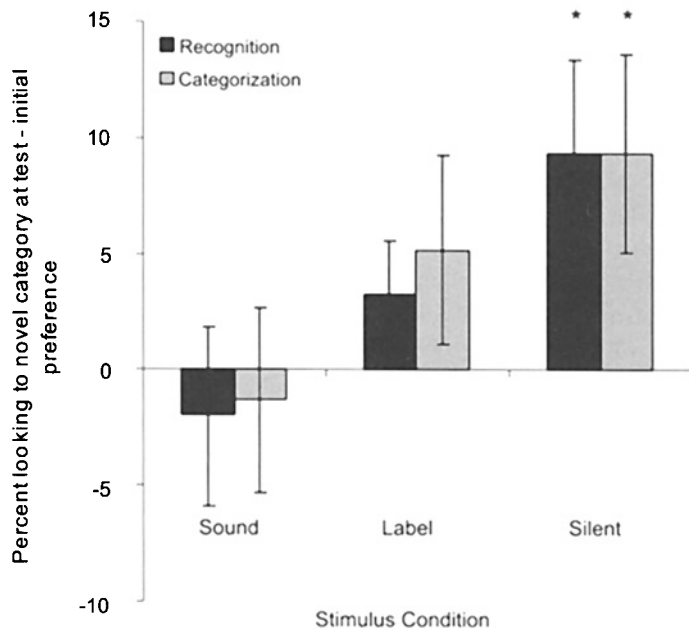


FIGURE 3 Difference scores on contrast trials (recognition) and test trials (categorization) across stimulus condition in Experiment 2. Error bars represent standard errors of the mean. *Note.* * $p < .05$, different from 0.

In summary, numerous methodological changes were made in Experiment 2 to create a more sensitive task to further examine the effects of auditory input on 8-month-olds' categorization and recognition memory. The most significant changes were increasing the number of familiarization trials, assessing initial preferences and recognition (i.e., contrast trials) prior to assessing categorization, reducing the number of exemplars within the familiarization category, using a less familiar category, assessing categorization after different amounts of familiarization, and presenting stimuli in pairs rather than isolation. Although some of these changes increased the complexity of the task, they had only small effects on infants' categorization performance: Categorization performance increased in the silent and label conditions by approximately 3% compared to Experiment 1 (see Figure 4 for aggregated findings). Thus, despite these numerous changes, Experiment 2 closely replicated the overall pattern found in Experiment 1: Infants looked longer to visual stimuli accompanied by sounds or labels, but these infants were less likely to form a category than infants in the silent condition. Therefore, these findings are sufficiently robust and are not specific to age, stimulus set, or presentation mode. In addition, Experiment 2 demonstrates that infants in the auditory conditions were also less likely to encode individual stimuli compared to infants who heard no auditory input.

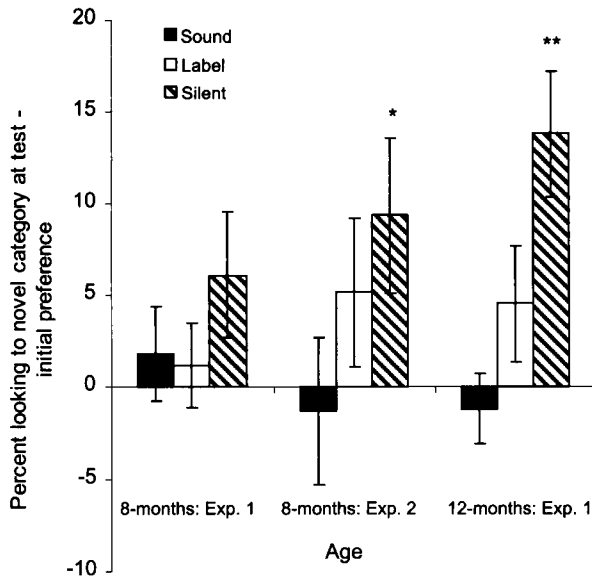


FIGURE 4 Categorization performance aggregated across experiments. Error bars represent standard errors of the mean. *Note.* * $p < .05$, different from 0. ** $p < .001$, different from 0.

GENERAL DISCUSSION

The reported experiments reveal several important findings. First, although it is widely believed that labels facilitate categorization in infancy, this study demonstrated that infants were more likely to learn a category in the silent condition than in the label or sound conditions (Experiments 1 and 2). Second, although infants in the silent condition accumulated less looking during familiarization compared to infants in the label and sound conditions, infants in the silent condition were more likely to encode (and recognize) the familiarization stimuli and form categories. Finally, although Experiments 1 and 2 used substantially different stimuli and procedures, both experiments produced the same overall pattern of results, suggesting that the findings are robust and not specific to age, stimulus sets, or presentation mode (i.e., single vs. paired comparison).

Labels and Categorization

Although most researchers agree that the effects of labels on category learning become more refined in the course of development, there are substantial differences as to effects of labels on categorization in prelinguistic infants. Recall that it has been argued that labels facilitate categorization more than other types of stimuli

because from the onset of word learning infants have general assumptions that words and categories are linked (Waxman, 2003). An alternative possibility is that both labels and sounds overshadow corresponding visual input, with sounds exerting greater overshadowing effects than labels. The reported findings support the latter view: Across the reported experiments, there was no evidence that categorization performance in the label condition exceeded the silent condition.

At the same time, the reported findings are consistent with the idea that early in development, auditory information dominates visual information, with unfamiliar sounds having greater overshadowing effects than words (Robinson & Sloutsky, 2004a, 2004b). It seems that overshadowing effects can explain the fact that categorization (and recognition) performance was better in the silent condition than in the two auditory conditions, whereas differential overshadowing can explain the fact that performance was worse in the sound condition than in the label condition. That is, if both labels and sounds overshadow (or attenuate processing of) corresponding visual input, participants should be less likely to process visual input in the two auditory conditions than in the silent condition. In addition, if unfamiliar auditory stimuli exert greater overshadowing effects than labels, this would explain why sounds hindered category learning more than labels.

Although this study did not find evidence that auditory input facilitated categorization above a no-auditory baseline, it is important to note that auditory information clearly affected behavior: Infants accumulated more looking when images are associated with labels and sounds. These findings replicate previous research using various procedures (e.g., Balaban & Waxman, 1997; Baldwin & Markman, 1989; Xu, 2002). However, even though 8- and 12-month-olds in this study looked significantly more to the visual images during familiarization in the sound and label conditions, only the silent condition yielded reliable category responding. One explanation for this finding may be that infants' attention during familiarization in the auditory stimulus conditions was primarily directed to the auditory stimulus, and the auditory stimulus overshadowed corresponding visual input. However, because this experiment did not assess encoding of auditory stimuli, it is also possible that the auditory stimulus simply interfered with forming categories (e.g., auditory stimulus added complexity to the task). Although this study cannot distinguish between these explanations, both explanations are inconsistent with the claim that labels facilitate category learning in young infants.

Unresolved Issues and Future Directions

How do young infants acquire word-object and word-category associations if sounds and labels overshadow corresponding visual input? We have preliminary evidence that introducing auditory stimuli prior to a familiarization phase (and thus making them more familiar than visual stimuli) may in fact attenuate overshadowing effects and in some situations facilitate encoding of visual input (Rob-

inson et al., 2005; Sloutsky & Robinson, 2006; see also Fennell, 2006, for similar findings). For example, infants in Sloutsky and Robinson (2006) were more likely to encode visual stimuli when paired with a “prefamiliarized” auditory stimulus (sound or word) than when the same visual stimuli were presented in isolation. These findings indicate that familiarity may not only play a crucial role in eliminating auditory dominance effects, but it may also tune attention to corresponding visual input, which in turn, may facilitate categorization and possibly help infants individuate objects.

When effects of labels on categorization are found, there are two distinct mechanisms that may underlie these effects. One mechanism stems from the overshadowing hypothesis. In particular, if stimuli are massively similar (e.g., two different rabbits), labels may partially overshadow the visual stimuli, thus, facilitating categorization by decreasing the discriminability of these stimuli (Sloutsky, Robinson, & Timbrook, 2005). However, in this study, labels or sounds did not facilitate categorization relative to the silent condition.

An alternative possibility is that as phonological and morphosyntactic patterns in native language become more familiar, labels may start tuning attention to corresponding visual input, thus supporting both categorization (or detection of commonalities) and individuation (or detection of differences). Therefore, according to the former hypothesis, labels may facilitate categorization by attenuating attention to differences, whereas according to the latter hypothesis, labels may facilitate categorization by increasing attention to commonalities. However, more research is needed to distinguish between these two mechanisms.

Despite the multiple procedural differences in this study compared with those used by other researchers (e.g., Waxman & Booth, 2003; Waxman & Markow, 1995; but see Balaban & Waxman, 1997, for a comparable procedure), we replicated the pattern of results with labels and sounds having different effects on categorization, at least by 12 months of age (see Experiment 1). However, when categorization performance in the sound and label conditions was compared to the silent condition, these effects appeared to be driven by sounds interfering with category learning more than labels, as opposed to labels helping infants detect categories that would go undetected in the absence of linguistic input. Thus, we believe the most significant difference between these sets of studies is the use of a silent condition. However, a number of other factors differ between these studies (e.g., presence of experimenter, use of objects rather than pictures, etc.) that will need to be examined in future research. Although it is uncertain how these factors affect recognition and categorization performance, results of this research clearly indicate that under the current conditions, auditory input hindered categorization and recognition of corresponding visual input.

In addition to the methodological issues already reported, two other issues will need to be addressed in future research. First, it could be argued that there is a possible confound in this study. In particular, across both reported experiments, infants in

the silent condition were familiarized to a category in silence and tested in silence. In contrast, infants in the label and sound conditions heard auditory input during familiarization and were tested in silence. Thus, it is possible that the change from familiarization to test hindered infants' performance in the sound and label conditions. The current theoretical approach makes a clear prediction: If auditory input interferes with encoding of visual input and category learning, then adding an auditory stimulus at test (e.g., "Look, look") should have little influence on categorization performance because the necessary information was not adequately encoded in the first place. A second issue concerns the distinction between labels affecting the acquisition of novel categories and labels affecting infants' responding to familiar categories. Recall that the categories used in Experiments 1 and 2 were real categories (i.e., cats and turtles, respectively) and the labels denoting these categories differ in familiarity, as reported by parents (Fenson et al., 1994). Across both experiments, the same overall pattern was found with labels not facilitating infants' category responding to familiar or unfamiliar categories. Although these findings suggest that labels may have comparable effects on categorizing novel and familiar stimuli, this issue needs to be examined directly in future research.

CONCLUSIONS

Results of the two reported experiments indicate that auditory input (both labels and sounds) hindered recognition and categorization compared to a silent condition. These findings seem to stem from overshadowing of visual stimuli or from auditory stimuli interfering with visual processing. The reported results are consistent with domain-general proposals (e.g., Campbell & Namy, 2003; Smith, 1999; Smith, Jones, Landau, Gershkoff-Stowe, & Samuelson, 2002; Samuelson & Smith, 1999), which posit that infants do not initially assume that labels refer to categories; rather, this knowledge is acquired after infants have established a corpus of knowledge about words, objects, and the categories they denote.

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APPENDIX

Experiment 1

Familiarization Stimuli



Test Stimuli



Familiar Category



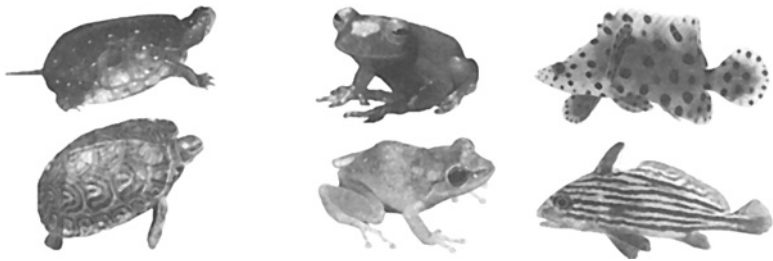
Novel Category

Experiment 2

Familiarization Stimuli



Test Stimuli



Familiar Category

Novel Categories