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The Role of Words and Sounds in Infants' Visual Processing: From Overshadowing to Attentional Tuning

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Abstract

Although it is well documented that language plays an important role in cognitive development, there are different views concerning the mechanisms underlying these effects. Some argue that even early in development, effects of words stem from top-down knowledge, whereas others argue that these effects stem from auditory input affecting attention allocated to visual input. Previous research (e.g., Robinson & Sloutsky, 2004a) demonstrated that non-speech sounds attenuate processing of corresponding visual input at 8, 12, and 16 months of age, whereas the current study demonstrates that words attenuate visual processing at 10 months but not at 16 months (Experiment 1). Furthermore, prefamiliarization with non-speech sounds (Experiment 2) resulted in able processing of visual input by 16-month-olds. These findings suggest that some effects of labels found early in development may stem from familiarity with human speech. The possibility of general-auditory factors underlying the effects of words on cognitive development is discussed.

Keywords: Attention; Cross-modal processing; Language development; Conceptual development

1. Introduction

Words play an important role in infants' and young children's performance on a variety of tasks. For example, there is evidence that as early as 9 months of age, infants are more likely to form object categories when different entities share a label (e.g., Balaban & Waxman, 1997), and by 13 to 21 months of age, children are more likely to generalize properties from a target object to a perceptually dissimilar test object when the test and the target items are associated with the same label (Graham, Kilbreath, & Welder, 2004; Welder & Graham, 2001). In addition, 9-month-olds are more likely to individuate objects in a set of two when each object is associated with a separate label (e.g., Xu, 2002, but see Robinson

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& Sloutsky, in press). Effects of words are also pronounced in preschool children. When two entities share a label, children are more likely to perceive these entities as looking more alike (Sloutsky & Fisher, 2004; Sloutsky & Lo, 1999), more likely to group these entities together (Sloutsky & Fisher, 2004), and more likely to make inferences from one entity to the other (Gelman & Markman, 1986; Sloutsky & Fisher, 2004; Sloutsky, Lo, & Fisher, 2001). Why do words play such an important role?

Various mechanisms have been proposed in an attempt to explain the importance of linguistic input, with some researchers arguing for language-specific effects and others arguing for more general effects. The language-specific proposal argues that linguistic input is a special class of stimuli. According to this view, words (especially count nouns) accompanying entities facilitate categorization of these entities because children understand that words refer to categories (Gelman & Coley, 1991; Markman & Hutchinson, 1984; see also Waxman, 2003). However, early in development, these effects are diffused, with count nouns, adjectives, and even content-filtered speech containing prosody exhibiting similar effects (Balaban & Waxman, 1997; Waxman & Booth, 2003; Waxman & Markow, 1995). In the course of development and learning, these effects become less diffused and limited only to count nouns (see Waxman, 2003, for a review). Thus, according to this view, effects of words are grounded in infants' and children's expectations that linguistic input and categories are linked (Waxman, 2003).

Another proposal argues that language-specific effects of words are a product of learning (e.g., Campbell & Namy, 2003; Namy & Waxman, 1998; Napolitano & Sloutsky, 2004; Smith, 1999; Smith, Jones, Landau, Gershkoff-Stowe, & Samuelson, 2002; Woodward & Hoyne, 1999). According to one variant of this view, effects of words may initially stem from the referential or communicative context in which words are introduced. Therefore, nonverbal signals (e.g., sounds or gestures) may initially exert effects similar to those of words as long as these signals are introduced in a communicative or referential context (e.g., Campbell & Namy, 2003; Namy & Waxman, 1998; Woodward & Hoyne, 1999).

Another variant of this view, which we refer to as the general-auditory proposal (e.g., Sloutsky & Napolitano, 2003), suggests that some of the effects of words stem from the modality of input, although linguistic and referential factors may amplify these general-auditory effects. Proponents of this view contend that some of the effects of linguistic input found early in development may stem from auditory information affecting attention allocated to corresponding visual input (Napolitano & Sloutsky, 2004; Robinson & Sloutsky, 2004a; Sloutsky & Napolitano, 2003), and these effects may change in the course of learning and development. The goal of the current research is to further test this hypothesis. In the next section, we review evidence generated by the general-auditory proposal. We then present five experiments designed to test the general-auditory hypothesis.

1.1. Evidence for general-auditory effects

The fundamental premise of the general auditory proposal—the idea that auditory information affects attention allocated to corresponding visual input—has been supported in a series of studies demonstrating that for infants and young children, auditory input often overshadows (i.e., attenuates processing of) corresponding visual input (Napolitano & Sloutsky, 2004;

Robinson & Sloutsky, 2004a; Sloutsky & Napolitano, 2003; see also Lewkowicz, 1988a, 1988b). For example, Sloutsky and Napolitano (2003) presented 4-year-olds and adults with an immediate recognition task. Participants were first presented with an auditory-visual target that consisted of an unfamiliar non-speech sound coupled with an unfamiliar visual stimulus. They were then presented with a test item that was either the original compound (Old Target) or a foil, in which either the visual or the auditory component was changed. Children and adults had to respond "Same" if the target and test were identical or "Different" if either the visual or auditory component changed. Despite the fact that visual and auditory components were equated for discriminability, 4-year-olds noticed the changed auditory component, while failing to notice the changed visual component, whereas adults noticed when either component changed. At the same time, 4-year-olds had no difficulty noticing the changed visual component when the same visual stimuli were not accompanied by auditory input. It was therefore concluded that sounds overshadowed visual information for 4-year-olds but not for adults.

To further investigate the developmental trajectory of auditory overshadowing effects, Robinson and Sloutsky (2004a) presented infants, 4-year-olds, and adults with the same auditory-visual compound stimuli (unfamiliar non-speech sounds coupled with either single shapes or with three-shape patterns). The infant task was similar to Sloutsky and Napolitano's (2003) task: 8-, 12-, and 16-month-olds were familiarized to an auditory-visual compound. During the test phase that followed the familiarization phase, either the auditory, visual, or both components changed. At test, infants noticed a change in the auditory component, as indicated by increased looking when the auditory component changed, and they often failed to notice a change in the visual component. Similar to young children in the Sloutsky and Napolitano (2003) study, infants encoded the same visual stimuli when presented in isolation, which suggests that the auditory stimulus attenuated processing of the corresponding visual input. Comparisons across the age groups indicated that this auditory dominance effect decreased with age: infants and young children were more likely than adults to fail to encode visual stimuli when paired with a sound, while ably discriminating the same visual stimuli when presented in isolation.

It has been argued that the general-auditory proposal (and auditory dominance in particular) can account for some of the effects of labels found in a variety of induction, categorization, and similarity judgment tasks (e.g., Sloutsky & Fisher, 2004; Sloutsky & Lo, 1999, for specific examples of these effects). In particular, in all these tasks, greater reliance on labels can stem from labels partially overshadowing corresponding visual input. While the ability of the general-auditory proposal to account for some of the effects of labels is promising, a number of critically important questions remain.

1.2. Unresolved issues and goals of current research

First, if auditory information overshadows visual information, how do infants form word-object associations, and how do children map novel words onto novel entities? More specifically, if participants attend only to words, but not to novel entities that the words accompany, such associations and mappings should be difficult, if not impossible. Yet infants do form word-object associations (e.g., Schafer & Plunkett, 1998; Werker, Cohen, Lloyd, Casasola, & Stager, 1998; Woodward, Markman, & Fitzsimmons, 1994) and young children do exhibit fast mapping (e.g., Carey & Bartlett, 1978; Markson & Bloom, 1997; see Woodward & Markman, 1998, for a review). And second, because previous research on auditory dominance primarily used nonlinguistic sounds, it is unclear whether auditory dominance effects will persist if sounds are substituted by words.

A tentative answer to the first question was offered by Napolitano and Sloutsky (2004): the key to resolving this apparent contradiction between overshadowing effects and infants' ability to form word-object associations and children's fast mapping is that both associations and fast mappings typically occur when objects and labels were presented repeatedly. It is possible that these multiple (and thus prolonged) presentations enabled infants and young children to encode both objects and words.

The second question is addressed directly in Experiment 1 of the current study. If for young infants words and sounds have similar effects on processing of corresponding visual input, then words should also overshadow corresponding visual input. However, given that at some point infants become capable of forming word-object associations, overshadowing effects of words should weaken or disappear in the course of development. Furthermore, if overshadowing effects disappear when visual stimuli are accompanied by words, it would be important to establish whether this reduced overshadowing is driven by language-specific factors or by more general factors. This issue is addressed in Experiment 2.

The overall goal of the reported experiments is to examine the effects of words on processing of corresponding visual input. In all experiments presented below, infants were first familiarized with an auditory-visual compound stimulus. Following familiarization, participants were tested on either the same compound stimulus that was presented during familiarization (Old Target) or on different compound stimuli that had a changed auditory component, a changed visual component, or both components changed. If participants encode the auditory or visual component during familiarization, then they should increase looking (compared to Old Target) when that component changes at test. To determine how different types of auditory input (i.e., unfamiliar sounds, words, and prefamiliarized sounds) affect processing of corresponding visual stimuli, encoding of the same visual input was compared across the different auditory conditions. These comparisons are important for determining whether the effects of words and sounds in cognitive tasks such as word learning, categorization, and individuation are also evident in low-level tasks such as cross-modal processing.

2. Experiment 1A

2.1. Method

2.1.1. Participants

Thirty-two 10-month-olds (15 boys and 17 girls, $M = 298$ days, $SD = 61$ days) and nineteen 16-month-olds (6 boys and 13 girls, $M = 489$ days, $SD = 9$ days) participated in this experiment. Parents' names were collected from local birth announcements and contact information was obtained through local directories. All children were full-term (i.e., > 2500 g birth weight) with no auditory or visual deficits, as reported by parents. A majority of infants were Caucasian. In addition to the 51 infants reported above, data provided by 24 infants were tested but not included in the following analyses: 9 infants were excluded due to fussiness and

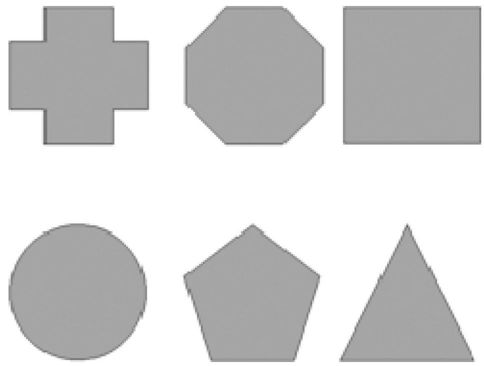

Fig. 1. Example of visual stimuli used in all experiments.

15 infants were excluded because they did not reach the inclusion criterion, which is discussed below.

2.1.2. Stimuli

Stimuli included a familiarization auditory-visual compound $AUD_{target}VIS_{target}$ and four auditory-visual test compounds, $AUD_{target}VIS_{target}$, $AUD_{target}VIS_{new}$, $AUD_{new}VIS_{target}$, and $AUD_{new}VIS_{new}$. The AUD_{target} and AUD_{new} components were two infant-directed nonsense labels (“vika” and “kuna”), which were produced by a female experimenter and recorded as 44.1 kHz wav files. The wav files were edited using Cool Edit 2000, and each label had a stimulus duration of 1000 ms. During the experiment proper, the labels were presented to infants by a Dell Dimension 8200 computer at 65–68 dB. The VIS_{target} and VIS_{new} components were two different three-shape patterns (circle, pentagon, triangle and cross, octagon, square). Individual shapes were green and the total three-shape pattern was projected to 25 cm × 7 cm in size (see Fig. 1 for both three-shape patterns). Previous research has demonstrated that infants of these age groups discriminate these visual images when presented in isolation; however, these images were overshadowed by unfamiliar non-speech sounds (Robinson & Sloutsky, 2004a).

2.1.3. Apparatus

Infants were seated on parents’ laps approximately 100 cm away from a 152 cm × 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 visual fixations. Fixations were recorded online by pressing a button on a 10-button USB gamepad when infants were looking at the stimulus and releasing the button when infants looked away from the stimulus. Presentation recorded a time stamp at the onset of a button press (look to stimulus) and recorded a time stamp when the button was released (look away from stimulus). Fixation durations were calculated for each look (i.e., button release − button press) and total looking was calculated on each trial by summing fixation durations within a trial. Two video streams (i.e., 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.

2.1.4. Procedure

The overall procedure is depicted in Fig. 2. The procedure consisted of two phases: familiarization and test. There were 10 familiarization trials, and each familiarization trial consisted of a compound stimulus ($AUD_{target}VIS_{target}$) that was repeatedly presented for 1000 ms and disappeared for 500 ms. The auditory and visual components were perfectly correlated (e.g., pulsated at the same rate) and both the auditory and visual stimuli were presented five times on each trial, resulting in a 7.5 s trial duration. Thus, in the current experiment and all following experiments, the auditory and visual components were presented for the same duration throughout familiarization. After 75 s of familiarization (10 familiarization trials), infants moved to the testing phase. At test, infants were presented with four different test trials ($AUD_{new}VIS_{target}$, $AUD_{target}VIS_{new}$, $AUD_{new}VIS_{new}$, and $AUD_{target}VIS_{target}$).

$AUD_{target}VIS_{target}$ (i.e., Old Target) and $AUD_{new}VIS_{new}$ (i.e., completely new item) were within subject controls to ensure that changes in the compound stimulus resulted in a novelty preference (i.e., infants' looking increased when both components changed relative to test trials where neither component changed). $AUD_{new}VIS_{target}$ and $AUD_{target}VIS_{new}$ trials indicated whether infants were primarily attending to auditory or visual input during familiarization, respectively. Test trials were 10.5 s in duration (each stimulus appeared 7 times), and the order of test trials was randomized. The four test trials were separated by three refamiliarization trials. The refamiliarization trials were the same as familiarization trials and were used to remind infants of the familiarization stimulus. Thus, after the 10 familiarization trials, infants were randomly presented with two test trials, three refamiliarization trials, and the remaining two test trials, respectively. Infants' looking was coded online throughout the entire procedure.

2.1.5. Interrater reliability

The recording of the split-screen apparatus described above was used for offline coding: a random sample of 25% 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, average $r = .93$.

2.2. Results and discussion

2.2.1. Inclusion criterion

The primary interest of the study was to investigate infants' encoding of auditory and visual stimuli across different auditory stimulus conditions, as indicated by increased looking to $AUD_{new}VIS_{target}$ and $AUD_{target}VIS_{new}$, respectively. To ensure that chance performance did not stem from half of the infants demonstrating a familiarity preference and half of the infants demonstrating a novelty preference, only infants who demonstrated a

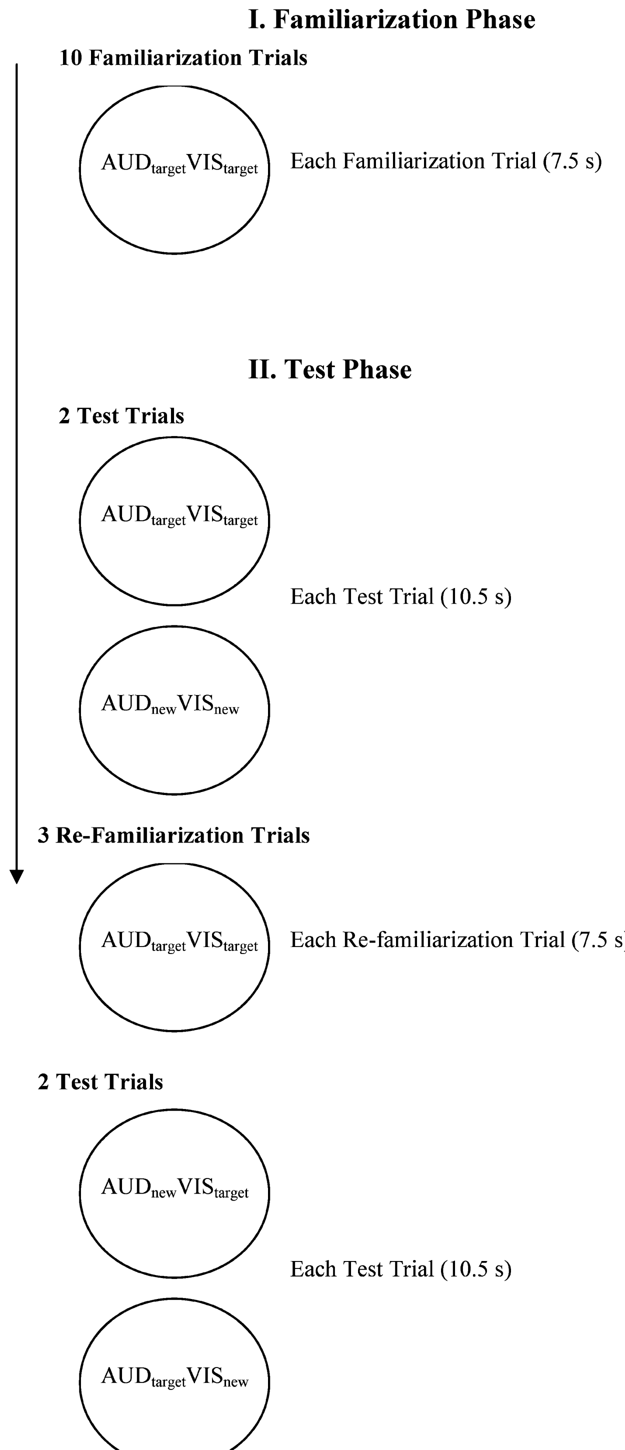

Fig. 2. Overview of procedure. Order of test trials was randomized for each infant.

Table 1
Averaged looking across familiarization trials 1–3 and 8–10, absolute looking to each test trial type, and different scores (compared to old target) from Experiment 1A

	Familiarization Phase		Test Phase						
			Absolute Looking				Difference Scores		
Age in Months	Trials 1–3	Trials 8–10	AUD_{target} VIS_{target}	AUD_{new} VIS_{target}	AUD_{target} VIS_{new}	AUD_{new} VIS_{new}	AUD_{new} VIS_{target}	AUD_{target} VIS_{new}	AUD_{new} VIS_{new}
10	6491	4737	4356	7503	4589	8121	3147	233	3765
16	6813	4398	4682	8085	6999	8716	3403	2317	4033

Note. All means are presented in milliseconds.

novelty preference in the control items were included in the following analyses. That is, only those infants who looked longer to the completely new item than the Old Target (i.e., $AUD_{new}VIS_{new} > AUD_{target}VIS_{target}$) were considered novelty responders and were included in the final sample. Responses of participants exhibiting a familiarity preference (i.e., those who looked longer to the Old target than to the completely new item) were analyzed separately.

Fifteen of the infants (twelve 10-month-olds and three 16-month-olds) were categorized as familiarity responders—they accumulated significantly more looking on $AUD_{target}VIS_{target}$ trials ($M = 8074$ ms, $SE = 520$ ms) than on $AUD_{new}VIS_{new}$ trials ($M = 6701$ ms, $SE = 613$ ms), $t\,(14) = -4.31, p < .001$, which suggests that discrimination on other test items should correspond with a decrease rather than increase in looking. However, these familiarity responders were inconsistent in their responding. Although they looked longer on $AUD_{target}VIS_{target}$ items than on $AUD_{new}VIS_{new}$ items, they also looked longer at completely new $AUD_{new}VIS_{new}$ items than on partially familiar $AUD_{target}VIS_{new}$ items ($M = 4835$ ms, $SE = 853$ ms), $t\,(14) = -1.84$, $p < .05$ (one-tailed), which is inconsistent with familiarity preferences. These infants, therefore, were excluded from further analyses.

2.2.2. Familiarization trials

Looking times across familiarization and test trials are presented in Table 1. As can be seen in the table, there were no effects of age on looking to familiarization trials, with participants of both age groups exhibiting reduced looking in the last three trials compared to the first three trials. This was confirmed by a 2 (age: 10 months vs. 16 months) × 2 (time: first three trials vs. last three trials) ANOVA with time as a repeated measure. The analysis indicated that infants' looking to the familiarization stimulus decreased across the familiarization phase from 6611 ms during the first three familiarization trials to familiarization 4611 ms during the last three familiarization trials of 4611 ms, $F\,(1, 49) = 84.44, p < .001$. Neither the main effect of age nor the interaction were significant, ps $> .15$.

2.2.3. Test trials

Analysis of test trials focused on infants' encoding of auditory and visual input. A difference score was calculated by taking the accumulated looking to each test item and subtracting

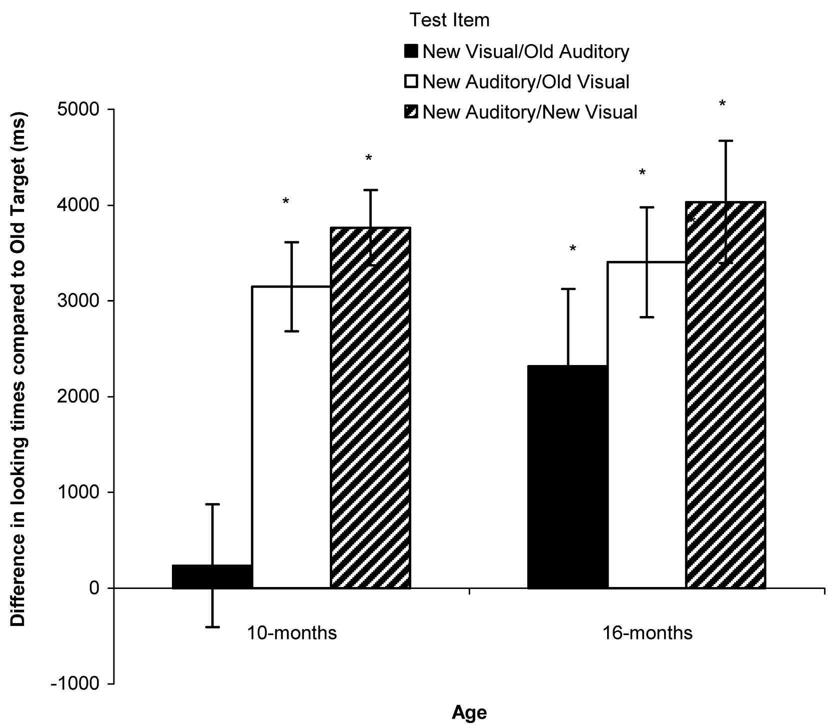

Fig. 3. Differences in looking times by age and test item type in Experiment 1A. Error bars represent standard errors of the mean. Note: *Difference scores > 0, $p < .05$.

accumulated looking time to Old Target from it (e.g., the effect of changing the auditory component = $AUD_{new}VIS_{target} - AUD_{target}VIS_{target}$). Thus, positive numbers indicate that looking increased as a function of changing a specific stimulus component, which suggests that infants encoded that modality during familiarization. Difference scores by test item and age group are presented in Fig. 3 (see Table 1 for absolute looking to each test item). The difference scores were subjected to a 2 (age: 10 months vs. 16 months) × 3 (test trial: $AUD_{new}VIS_{target}$, $AUD_{target}VIS_{new}$, $AUD_{new}VIS_{new}$) mixed ANOVA. The analysis revealed a main effect of test trial, F (2, 98) = 19.00, $p < .001$, with participants increasing looking more when the auditory component changed ($AUD_{new}VIS_{target}$ = 3242 ms, SE = 359 ms) and when both components changed ($AUD_{new}VIS_{new}$ = 3865 ms, SE = 340 ms) than when only the visual component changed ($AUD_{target}VIS_{new}$ = 1010 ms, SE = 517 ms), paired sample ts > 4.00, all ps < .001. In addition, infants increased looking more when both components changed than when only the auditory component changed, t (50) = 1.93, p = 059.

The above analysis also revealed an Age × Test Trial interaction, F (2, 98) = 2.80, p = .066. Planned comparisons indicated that there were no differences across age groups in detecting a changed auditory component, independent sample t (49) = 0.34, p = .73, whereas 16-month-olds were significantly more likely to detect changes in the visual component than the 10-month-olds, independent sample t (49) = 2.01, $p < .05$, with only the 16-month-olds increasing looking above 0 when the visual component changed, one sample t (18) = 2.88,

$p < .01$. Thus, although both age groups ably encoded labels, encoding of the visual component changed considerably between 10 and 16 months of age, with only 16-month-olds reliably encoding the visual component. Therefore, when visual stimuli were accompanied by words, 10-month-olds, but not 16-month-olds, exhibited evidence of auditory overshadowing (or attenuated processing of corresponding visual input).

Could it be that younger infants merely failed to discriminate the visual component of compound stimuli? Experiment 1B was conducted to ensure that 10-month-olds could discriminate the visual stimuli when these stimuli are presented unimodally.

3. Experiment 1B

3.1. Method

3.1.1. Participants

Forty-four 10-month-olds (28 boys and 16 girls, $M = 296$ days, $SD = 61$ days) participated in the control experiment. Recruitment procedures and demographics were identical to Experiment 1A. In addition to the 44 infants reported above, data provided by an additional 30 infants were tested but not included in the following analyses: 7 infants were excluded due to fussiness and 23 infants were excluded because they did not reach the inclusion criterion (10 infants in the auditory condition and 13 infants in the visual condition).

3.1.2. Stimuli and procedure

The specific auditory and visual components were identical to Experiment 1A; however, the presentation of these stimuli differed from the previous experiment: the auditory and visual components were not presented together in the current experiment; thus, discrimination of the auditory stimuli ($n = 23$) and visual stimuli ($n = 21$) was assessed separately in the current experiment. For example, infants in the visual, unimodal baseline were familiarized to a visual stimulus presented in isolation (i.e., VIS_{target}). The visual stimulus pulsated at the same rate as in Experiment 1A (i.e., 1000 ms stimulus duration with a 500 ms inter-stimulus interval). After 75 s of familiarization, infants moved to the testing phase, where they were presented with a new visual stimulus (i.e., VIS_{new}), the old familiarization stimulus (i.e., VIS_{target}), and a recovery stimulus (i.e., red car), respectively. As in Experiment 1A, test trials were 10.5 s in duration, and only infants who showed a novelty preference were included in following analyses. The recovery stimulus served as an independent measure for categorizing each infant as a novelty or familiarity responder. More specifically, infants who looked longer to the recovery stimulus than the familiarization stimulus (i.e., looking to recovery stimulus $> VIS_{target}$) were considered novelty responders. In contrast, participants looking longer to the familiarization stimulus than to the recovery stimulus (i.e., $VIS_{target} >$ recovery stimulus) were considered familiarity responders. The auditory condition was isomorphic to the visual condition. Infants were familiarized to a linguistic label, and at test they were presented with a new label, the familiarized label, and a recovery stimulus, respectively. In contrast to the previous experiment, a fixation light that was added prior to each familiarization and test trial to ensure that the infant made at least one fixation on each trial.

3.2. Results and discussion

In contrast to Experiment 1A, under the unimodal presentation condition of Experiment 1B, 10-month-olds encoded both the label and the visual stimulus. In particular, infants increased looking to the changed stimulus (i.e., difference scores > 0) when the label changed at test ($M = 2854$ ms, $SE = 609$ ms) and when the visual stimulus changed at test ($M = 1239$ ms, $SE = 594$ ms), one-sample ts > 2.00, ps $< .05$. Therefore, infants discriminated both visual and auditory stimuli (although discrimination of auditory stimuli was somewhat greater than that of visual stimuli).

To ascertain that 10-month-olds' successful discrimination of the visual stimuli in the current experiment did not result from excluding a significant proportion of the sample, we examined those 13 infants who demonstrated a familiarity preference and thus were excluded from the final sample. As with novelty responders, excluded infants also discriminated the visual stimuli: infants significantly decreased looking when the visual stimulus changed at test ($VIS_{new} - VIS_{target} = -1055$ ms, $SE = 569$ ms), $t\,(12) = -1.85$, $p < .05$ (one-tailed). Given that both familiarity and novelty responders discriminated the visual stimuli when presented in isolation, it is unlikely that results of Experiment 1A stemmed from the inability of 10-month-olds to discriminate the visual input. Results of Experiment 1B support the idea that the attenuated visual discrimination found in Experiment 1A resulted from labels overshadowing the visual stimuli at 10 months of age.

The results of the current study, in conjunction with Robinson and Sloutsky (2004a), suggest that unfamiliar labels (used in the current study) and unfamiliar non-speech sounds (used by Robinson & Sloutsky, 2004a) have similar effects on processing visual input early in development: both unfamiliar labels and unfamiliar non-speech sounds appear to overshadow corresponding visual input between 8 and 12 months of age. In contrast, 16-month-olds in the current experiment encoded the visual stimuli when associated with a label, while failing to encode these same visual stimuli when they were associated with unfamiliar, nonlinguistic sounds (Robinson & Sloutsky, 2004a). Taken together, these two sets of results suggest that early in development words and sounds exert similar effects on processing of corresponding visual input: both words and sounds attenuate processing of corresponding visual input, thus exhibiting overshadowing effects. At the same time, at 16 months of age, words and sounds start having different effects on processing of corresponding visual input: while sounds continue to overshadow visual input, words do not interfere with processing of visual input.

Why is there a difference between encoding visual stimuli accompanied by words and by sounds at 16 months of age? We consider two possibilities. First, according to a language-specific hypothesis, it is possible that human speech is a special class of stimuli for humans, with infants and young children having broad assumptions that words refer to categories (e.g., Waxman & Booth, 2003). Thus, from this perspective, labels may play a special role in processing of visual information by directing children's attention to visual input (e.g., Balaban & Waxman, 1997; Baldwin & Markman, 1989; Xu, 2002). Alternatively, it is possible that increased processing of visual input in the label condition stems from familiarity effects as opposed to linguistic effects: human speech is more familiar than many other sounds (e.g., Jusczyk, 1998; Napolitano & Sloutsky, 2004) and, under repeated presentation conditions, more familiar stimuli may be processed faster and may be less likely to interfere with processing of visual stimuli. If familiarity can account for the increased processing of visual input, then prefamiliarizing infants to the nonlinguistic sounds prior to the experiment proper should attenuate overshadowing effects. While several encounters with nonlinguistic sounds in the laboratory might not be completely isomorphic to 16-month-olds' real-world experiences with human speech, it is possible that hearing an auditory stimulus several times prior to being paired with a visual stimulus may result in faster processing of the auditory stimulus, thus allowing for more time to process the corresponding visual stimulus. However, if the increased processing of visual input stems from language-specific effects, then familiarity of nonlinguistic sounds should have no affect on overshadowing effects. This issue was addressed in Experiment 2A.

4. Experiment 2A

Experiment 2A focused only on 16-month-olds' processing of visual input: recall that 10-month-olds in Experiment 1A replicated Robinson and Sloutsky (2004a), whereas labels and sounds had different effects at 16 months of age. The procedure used in Experiment 2A was similar to the previous experiment; however, the labels used in Experiment 1A were replaced by the same nonlinguistic sounds used in Robinson and Sloutsky's study. At the same time, in contrast with Robinson and Sloutsky (2004a), participants were prefamiliarized to these auditory stimuli prior to the experiment proper.

4.1. Method

4.1.1. Participants

Sixteen 16-month-olds (8 boys and 8 girls, $M = 492$ days, $SD = 9$ days) participated in this experiment. Recruitment procedures and demographics were identical to Experiment 1A. Data provided by 5 infants were not included in the following analyses: 2 infants were excluded due to fussiness and 3 infants were excluded because they did not reach the inclusion criterion.

4.1.2. Stimuli and procedure

The visual stimuli were identical to Experiment 1A and the auditory stimuli consisted of the same nonlinguistic sounds (i.e., laser sound and static sound) used in Robinson and Sloutsky's (2004a) study. Both nonlinguistic sounds were 44.1 kHz wav files and edited using Cool Edit 2000. As in Experiment 1A, the nonlinguistic sounds were presented by the computer at 65–68 dB and were perfectly correlated with the visual stimulus (i.e., both the auditory and visual stimuli had a 1000 ms stimulus duration and a 500 ms inter-stimulus interval).

Prior to the experiment proper, infants participated in a prefamiliarization phase. During prefamiliarization, infants sat on parents' laps and heard the same two auditory stimuli that were used in the experiment proper. Each auditory stimulus was presented 10 times, and the auditory stimuli were not associated with any visual images during prefamiliarization. Thus, while participants were prefamiliarized with the auditory component, the visual components remained unfamiliar. After the prefamiliarization phase, infants were given a short break and

Table 2
Averaged looking across familiarization trials 1–3 and 8–10, absolute looking to each test trial type, and different scores (compared to old target) are presented across the different stimulus conditions at 16 months

Auditory Stimulus (Experiment Number)	Familiarization Phase		Test Phase						
			Absolute Looking				Difference Scores		
	Trials 1–3	Trials 8–10	AUD_{target} VIS_{target}	AUD_{new} VIS_{target}	AUD_{target} VIS_{new}	AUD_{new} VIS_{new}	AUD_{new} VIS_{target}	AUD_{target} VIS_{new}	AUD_{new} VIS_{new}
Unfamiliar labels (1A)	6813	4398	4682	8085	6999	8716	3403	2317	4033
Prefamiliarized sounds (2A)	6847	4965	5040	8501	9132	10,408	3461	4092	5369
Prefamiliarization control (2C)	7084	5118	6746	9871	8374	10,173	3124	1627	3427
No-auditory baseline (2B)	6818	4643	5067	—	6861	—	—	1794	—

Note. All means are presented in milliseconds. Values in the test phase of the No-auditory baseline represent looking to VIS target and VIS new.

then they participated in the experiment proper. The procedure of the experiment proper was identical to Experiment 1A, except that the infant-directed nonsense labels used in Experiment 1A were replaced with prefamiliarized non-speech sounds.

4.2. Results and discussion

4.2.1. Familiarization trials

Looking times across familiarization and test trials are presented in Table 2. As can be seen in the table, participants reduced looking in the last three trials compared to the first three trials. This was confirmed by an ANOVA with time (first three trials vs. last three trials) as a repeated measure. Infants' looking to the familiarization stimulus decreased across the familiarization phase, $F(1, 15) = 14.83$, $p < .005$, with the average accumulated looking during the first three familiarization trials of 6847 ms and the average accumulated looking during the last three familiarization trials of 4965 ms.

4.2.2. Test trials

If stimulus familiarity can account for the increased processing of the visual stimulus, then 16-month-olds should ably process the visual stimulus when paired with a prefamiliarized nonlinguistic sound. Differences in looking at each test item compared to looking to the Old Target (i.e., $AUD_{target}VIS_{target}$ item) are presented in Fig. 4, and absolute looking across the different test items and stimulus manipulations are presented in Table 2. As can be seen in the figure, infants in the prefamiliarized sound condition ably processed both the visual and the auditory components: infants increased looking when the auditory, visual, and both components changed at test, all differences > 0, one-sample ts > 4.00, ps < .001. In addition, infants increased looking more when both components changed than when only the auditory

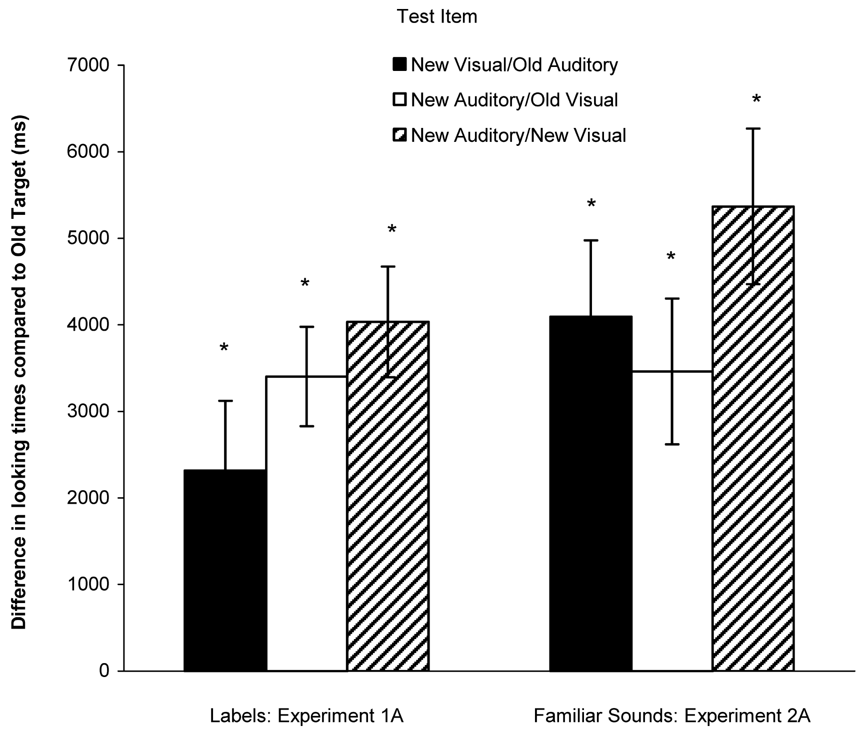

Fig. 4. Differences in 16-month-olds' looking times by test item type in Experiments 1A and 2A. Error bars represent standard errors of the mean. *Note*: *Difference scores > 0, $p < .05$.

component changed or when only the visual component changed, paired sample ts > 2.00, ps $< .05$. No other effects were significant. Thus, prefamiliarizing infants to the sounds facilitated processing of the visual stimulus: when 16-month-olds were presented with the same auditory-visual stimuli and the auditory stimuli were not prefamiliarized, infants failed to encode the visual component (Robinson & Sloutsky, 2004a).

5. Experiment 2B

Given the robust encoding of visual input demonstrated by 16-month-olds in Experiments 1A and 2A, we deemed it necessary to examine whether words and prefamiliarized sounds (a) merely did not interfere with processing of visual stimuli or (b) effectively tuned attention, thus facilitating encoding of corresponding visual input. To distinguish between these possibilities, we compared discrimination of visual stimuli under the bimodal conditions of Experiments 1A and 2A with a unimodal no-auditory baseline. If labels and prefamiliarized sounds simply do not interfere with visual processing, then no differences should be found between discrimination in the bimodal conditions and in the unimodal baseline. On the other hand, tuning effects could be inferred from better discrimination of visual stimuli in the bimodal condition than in the no-auditory baseline.

5.1. Method

5.1.1. Participants

Twenty 16-month-olds (9 boys and 11 girls, $M = 494$ days, $SD = 8$ days) participated in the current experiment. Recruitment procedures and demographics were identical to previous experiments. Two infants were excluded because they did not reach the inclusion criterion.

5.1.2. Stimuli and procedure

The experiment was identical to the visual unimodal baseline task reported in Experiment 1B. In particular, infants were familiarized to one of the visual patterns (i.e., VIS_{target}). After familiarization, they moved to the testing phase, where they were presented with a new visual stimulus (i.e., VIS_{new}), the old familiarization stimulus (i.e., VIS_{target}), and a recovery stimulus (i.e., red car), respectively. Discrimination was inferred from increased looking to VIS_{new} compared to VIS_{target}.

5.2. Results and discussion

5.2.1. Familiarization trials

An ANOVA with time (first three trials vs. last three trials) as a repeated measure revealed that infants' looking to the familiarization stimulus decreased across the familiarization phase, $F(1, 19) = 29.27$, $p < .001$, with the average accumulated looking during the first three familiarization trials of 6818 ms and the average accumulated looking during the last three familiarization trials of 4643 ms.

5.2.2. Test trials

Infants increased looking when the visual stimulus changed at test compared to Old Target ($M = 1794$ ms, $SE = 747$ ms), one-sample $t\,(19) = 2.40$, $p < .05$. However, the primary aim of the no-auditory baseline condition was to determine if prefamiliarized sounds (Experiment 2A) and unfamiliar labels (Experiment 1A) tune attention to the visual stimulus, thus facilitating processing of this stimulus compared to the no-auditory baseline. Encoding of the visual stimulus in Experiments 1A and 2A, as well as encoding of the same visual stimulus in the no-auditory baseline of Experiment 2B, are presented in Fig. 5. As can be seen in the figure, infants prefamiliarized to the nonlinguistic sounds exhibited increased processing of the visual stimulus relative to the no-auditory baseline, independent sample $t\,(34) = 2.00$, $p = .054$. While unfamiliar labels did not overshadow visual input at 16 months, they had no significant effect relative to the no-auditory baseline condition, independent sample $t\,(37) = 0.48$, $p = .64$.

6. Experiment 2C

Experiments 2A and 2B demonstrate that prefamiliarizing infants to an auditory stimulus increased the processing of the corresponding visual input; however, there are several possible explanations that can account for this finding. First, it is possible that the prefamiliarization procedure (and not familiarity with the specific auditory stimuli) affected infants' behavior

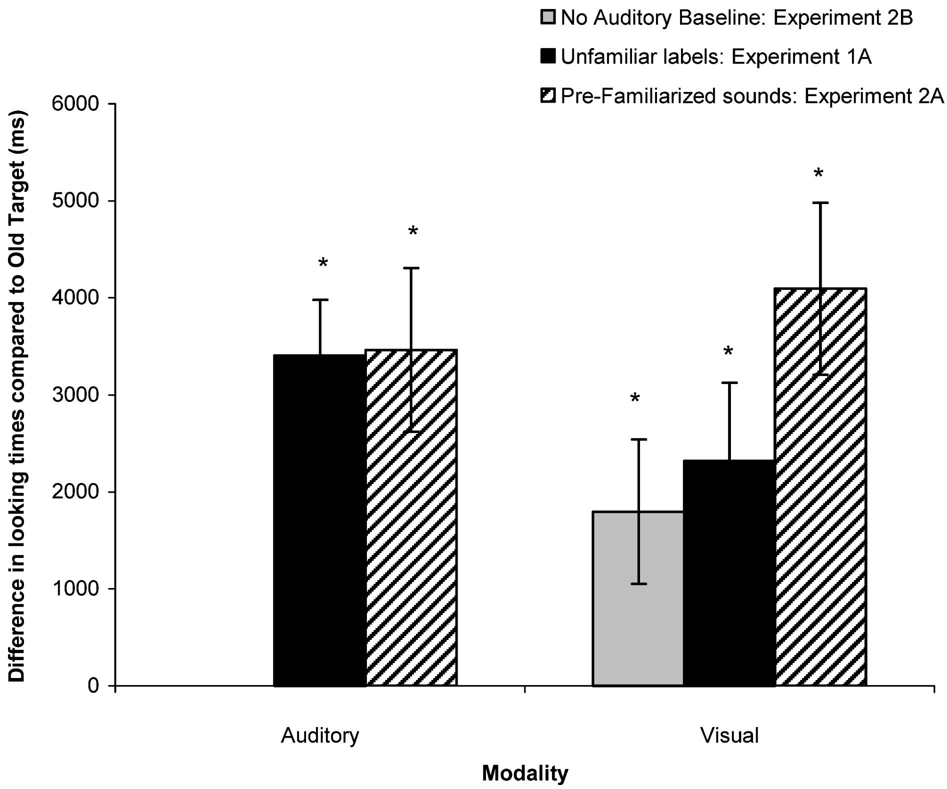

Fig. 5. Differences in 16-month-olds' looking times by modality and auditory condition in Experiments 1A, 2A, and 2B. Error bars represent standard errors of the mean. *Note*: *Difference scores > 0, $p < .05$.

during the experiment proper. More specifically, it is possible that (a) the prefamiliarization phase gave infants time to warm up to the testing room and apparatus and/or (b) the repeated exposure to any auditory stimulus during prefamiliarization increased attention allocation to visual stimuli at a later time (due to habituation to the auditory modality more generally). According to (a) and (b), any warm-up task or procedure that repeatedly presents any type of auditory stimulus should affect performance on a subsequent task. Alternatively, it is possible that familiarity with the specific auditory stimuli affected infants' encoding of a visual input. The goal of Experiment 2C was to distinguish between these possibilities: infants in Experiment 2C participated in the same prefamiliarization phase as in Experiment 2A; however, the auditory stimuli presented during prefamiliarization were not the same as the auditory stimuli that were presented during the experiment proper. It was expected that the current manipulation would not result in increased discrimination of visual input.

6.1. Method

6.1.1. Participants

Sixteen 16-month-olds (11 boys and 5 girls, $M = 488$ days, $SD = 7$ days) participated in this experiment. Recruitment procedures and demographics were identical to previous experiments. Data provided by 6 infants were not included in the following analyses: one infant was excluded due to fussiness and 5 infants were excluded because they did not reach the inclusion criterion.

6.1.2. Stimuli and procedure

The stimuli and procedure were identical to Experiment 2A, except that infants were prefamiliarized to the labels from Experiment 1A and then they heard the nonlinguistic sounds from Experiment 2A in the experiment proper. In particular, infants heard each linguistic label 10 times during prefamiliarization, and these labels were not associated with any visual images. After a short break, infants participated in the experiment proper, which was identical to Experiment 2A. However, in contrast to Experiment 2A, the nonlinguistic sounds were unfamiliar at the beginning of the experiment proper.

6.2. Results and discussion

6.2.1. Familiarization trials

An ANOVA with time (first three trials vs. last three trials) as a repeated measure revealed that infants' looking to the familiarization stimulus decreased across the familiarization phase, $F(1, 15) = 22.82$, $p < .001$, with the average accumulated looking during the first three familiarization trials of 7084 ms and the average accumulated looking during the last three familiarization trials of 5118 ms.

6.2.2. Test trials

If the prefamiliarization phase can account for the reported tuning effects, then infants in this condition should also be more likely to encode the visual stimulus compared to the no-auditory condition. Infants in this condition did not significantly increase looking to the visual stimulus ($AUD_{target}VIS_{new} - AUD_{target}VIS_{target} = 1627$ ms) compared to the no-auditory baseline, independent sample $t\,(34) = -0.18$, $p = .86$.

It could be argued, however, that the difference between Experiments 2B and 2C stemmed from infants being confused in Experiment 2C because they heard speech sounds during the prefamiliarization phase but heard non-speech sounds during the experiment proper (i.e., the familiarization and testing phases). However, this possibility seems unlikely: if infants were confused by this change in the auditory stimuli (and hence surprised), then their looking during the familiarization part of the experiment proper should have reflected this surprise. However, this was not the case—infants in the experiment proper substantially decreased looking across familiarization trials.

Therefore, results of Experiments 2A–2C demonstrate that the prefamiliarized sounds facilitate visual discrimination, thus suggesting that familiar auditory input could facilitate visual processing. Additional support for this idea stems from findings that prefamiliarized non-speech sound also speed up the processing of corresponding visual input (Robinson & Sloutsky, 2007a). Note that the current paradigm (which used fixed-trial durations) does not allow for across-condition comparisons of visual processing during the familiarization phase. This is because each familiarization trial had a fixed duration of 7.5 seconds, as opposed to being contingent on infants' looking. Therefore, it is possible that looking times were differentially truncated in the different conditions. At the same time, our recent research using a continuous familiarization paradigm suggests that familiarity with the auditory input is likely to affect visual discrimination by changing the speed of visual processing (Robinson & Sloutsky, 2007a). In particular, prefamiliarized sounds resulted in faster visual processing than unfamiliar sounds, with infants who heard prefamiliarized sounds requiring less familiarization before reliably discriminating the visual images.

7. General discussion

7.1. Summary of findings

The reported experiments reveal several important findings. First, unfamiliar linguistic labels were found to overshadow corresponding visual stimuli at 10 months of age. These findings were similar to the effects found for nonlinguistic sounds at 8 and 12 months of age (Robinson & Sloutsky, 2004a). In contrast, at 16 months of age, linguistic labels did not interfere with processing of corresponding visual input, whereas nonlinguistic sounds did exhibit overshadowing effects (Robinson & Sloutsky, 2004a). Furthermore, as shown in Experiment 2A, able processing of visual input by 16-month-olds is likely to stem from familiarity factors rather than from language-specific (or communication-specific) factors.

And finally, familiarizing 16-month-olds with nonlinguistic sounds resulted in elevated processing of corresponding visual stimuli—these visual stimuli were more likely to be processed when they were accompanied by prefamiliarized sounds than when the same stimuli were presented without auditory input (no-auditory baseline). Therefore, prefamiliarization with auditory stimuli attenuate overshadowing effects and may result in tuning attention to corresponding visual stimuli.

7.2. General auditory proposal: Overshadowing and tuning effects

This research in conjunction with previously published reports (e.g., Robinson & Sloutsky, 2004a) elucidates effects of auditory information on processing of corresponding visual information early in development. Under some conditions, auditory information hinders processing of corresponding visual information (i.e., overshadowing effects), whereas under other conditions auditory information facilitates processing of corresponding visual information (i.e., tuning effects). Although the current study did not manipulate the discriminability of the auditory or visual stimuli (which would have enabled delineating the scope of overshadowing effects), the current study brings critical evidence demonstrating that encoding of the same visual stimuli varies depending on the accompanying auditory input.

We believe that overshadowing and tuning effects share the same underlying mechanism—they are likely to stem from the dynamics of allocation of attention in the course of cross-modal processing. First, auditory input often engages attention more quickly than visual input (e.g., Posner, Nissen, & Klein, 1976), which may underlie auditory overshadowing. In addition, allocation of attention seems to be mediated by stimulus familiarity and the length of processing. In particular, it seems that familiar stimuli (a) automatically engage attention

(Christie & Klein, 1995), (b) are processed faster than unfamiliar stimuli, and (c) are faster to release attention than unfamiliar stimuli (due to habituation effects). Therefore, early in the course of processing (i.e., after few presentations), familiar input should overshadow less familiar input (Napolitano & Sloutsky, 2004; Robinson & Sloutsky, 2004a), whereas later in processing (i.e., after multiple presentations), familiar auditory input may facilitate allocation of attention to novel information (i.e., the current study).

Familiarity of the auditory information is the only factor we can think of that can account for the finding that the same auditory stimuli can both overshadow visual input as in Robinson and Sloutsky (2004a) and facilitate visual processing, as was found in the current study. As mentioned above, familiar auditory stimuli may facilitate encoding of a visual stimulus late in the course of processing (tuning), whereas unfamiliar auditory stimuli may be slower to release attention and thus are likely to exert overshadowing effects both early and late in the course of processing. This explanation is not only consistent with the current findings but also consistent with research demonstrating that the familiarity of the auditory stimulus plays an important role in determining the speed of processing visual input, as indicated by the amount of familiarization needed before infants reliably discriminate visual images (Robinson & Sloutsky, 2007a).

Tuning effects reported here are of particular interest. It has often been reported that infants are more attentive, as indicated by more overall looking, when visual stimuli are associated with linguistic input than when visual stimuli presented in isolation (e.g., Balaban & Waxman, 1997; Xu, 2002, see also Baldwin & Markman, 1989, for similar findings), and compared to a no auditory baseline, this increase in attention may help infants form object categories (Fulkerson & Haaf, 2003; Roberts, 1995; but see Robinson & Sloutsky, 2007b). However, tuning effects go above and beyond increased looking—prefamiliarized auditory information actually facilitated processing of corresponding visual input. These findings (in conjunction with overshadowing effects) point to an important asymmetry: early in development, auditory information is more likely to affect processing of visual information than visual information is to affect processing of auditory information. This asymmetry has to be further examined in future research.

One remarkable sign of this asymmetry is that while familiarization with auditory stimuli affected processing of visual input, it did not affect processing of auditory input (see Table 2). This finding, as well as previously reported results using the same paradigm with 16-month-olds, suggests that regardless of the familiarity of auditory stimuli, these stimuli are processed ably, whereas processing of visual stimuli is, to a large extent, mediated by corresponding auditory stimuli. This asymmetry seems to support the notion that auditory information is more likely to alert attention than visual information (e.g., Posner et al., 1976).

7.3. Broader implications: language and conceptual development

There are multiple studies that have investigated the role of words and sounds in various cognitive tasks such as word learning, lexical extension, categorization, induction, and individuation (e.g., Balaban & Waxman, 1997; Campbell & Namy, 2003; Fulkerson, Waxman, & Seymour, 2006; Waxman & Booth, 2003; Welder & Graham, 2001; Woodward & Hoyne, 1999; Xu, 2002). There is an important commonality between the current task and all of these tasks: across all these tasks, infants and children had to attend to and process auditory and visual input. Given that processing of visual input is critical for performance on a variety of tasks, it seems likely that the dynamics of allocation of attention in the course of cross-modal processing that give rise to overshadowing and tuning effects would also affect performance on these tasks. Therefore, an understanding of how children process simultaneously presented auditory and visual input may be informative for understanding the mechanisms driving the effects of words in cognitive tasks.

Present findings in conjunction with earlier reports (Napolitano & Sloutsky, 2004; Robinson & Sloutsky, 2004a; Sloutsky & Napolitano, 2003) indicate that the prominent role of linguistic labels may be explained in part by general-auditory effects, which are mediated by familiarity of auditory stimuli. Although, these results do not rule out the language-specific or communication-specific explanations, they suggest that some effects of linguistic labels could stem from general-auditory factors. Alternatively, it could be argued that prefamiliarized sounds and unfamiliar labels both attenuated overshadowing effects through different mechanisms. Distinguishing between these two explanations is a goal of future research and will be discussed in more detail below.

7.4. Possible limitations and future directions

By focusing on infants' processing of auditory and visual input more generally, the current study may shed light on a variety of higher level tasks that hinge on these processes. Of course, such generalization requires some caution, given that there are methodological differences between the current task and tasks used to examine early word learning and effects of labels on a variety of cognitive tasks. One difference is that the visual stimuli used in the current study were complex three-shape patterns, whereas studies examining word learning and effects of labels on categorization and individuation use single objects. Given that infants typically encounter single objects and they map words onto these single objects, it could easily be argued that the complex three-shape patterns used in the current study were unnatural and therefore may potentially limit the generalizability of the current findings.

This issue has recently been examined in a series of studies examining children's processing of arbitrary auditory-visual pairings (Napolitano & Sloutsky, 2004; Sloutsky, Robinson & Timbrook, 2005), visual processing speed in infants (Robinson & Sloutsky, 2007a), and the effects of auditory input on categorization and individuation in young infants (Robinson & Sloutsky, 2007, in press, 2007b). In all of these studies, there is evidence that auditory stimuli can attenuate the discrimination of single objects, affect visual processing speed, interfere with object categorization, and interfere with the individuation of common objects such as duck and ball. Furthermore, consistent with the current study, many of these studies also demonstrate that cross-modal interference can be attenuated by increasing the familiarity of the auditory stimulus. Thus, although there are likely to be differences in processing single versus multi-object images, there is sufficient evidence to suggest that overshadowing and tuning effects are not limited to the processing of complex three-shape patterns.

It could also be argued that many of the effects found in the current study stem from equating the duration of the auditory and visual stimuli. While this manipulation was crucial in the current study to ensure that differences in the processing of auditory and visual input did not stem from differences in stimulus duration, it could be seen as a limitation of the current study. In particular, in real-word learning situations as well as in studies examining word learning and effects of auditory input on a variety of cognitive tasks, the visual stimuli are often presented for longer durations than the auditory stimuli. This methodological difference raises an important question: are overshadowing and tuning effects limited to situations where auditory and visual stimuli are equated in duration and presented in synchrony?

We have recent evidence indicating that even when visual stimuli are presented for extended periods of time, overshadowing effects do not completely disappear. For example, Robinson and Sloutsky (2007b) examined category learning in 8- and 12-month-old infants. Participants were familiarized with members of a category (e.g., cat) under one of the three conditions: in the baseline condition, pictures were not accompanied by any auditory stimulus; in the word condition, pictures were accompanied by a count noun (e.g., Look at the X); and in the sound condition, pictures were accompanied by a nonlinguistic sound. Participants were then tested on (a) studied items versus new items from a novel category and (b) new items from a studied category versus new items from a novel category, with the former testing recognition and the latter testing categorization. Although the visual stimuli in Robinson and Sloutsky's (2007b) study were single objects and were presented for an additional 7 s after the offset of the auditory stimulus, both recognition and categorization were often hindered by the presence of the sounds and labels.

We have additional evidence from a study using a continuous familiarization paradigm (see Fantz, 1964; Roder, Bushnell, & Sasseville, 2000; Rose, Feldman, & Jankowski, 2002, for similar procedures) to examine the effects of auditory input on visual processing speed (Robinson & Sloutsky, 2007a). On each familiarization trial infants were simultaneously presented with two visual stimuli: one visual stimulus remained unchanged across familiarization (i.e., familiar stimulus), whereas the other visual stimulus changed on every trial (i.e., novel stimulus). Processing speed was measured by the amount of familiarization needed before infants demonstrated a reliable novelty (or familiarity) preference for the visual images. Infants either heard a linguistic label or a nonlinguistic sound (unfamiliar, prefamiliarized, or presented in a referential context) at the onset of each familiarization trial. A separate group of infants heard no auditory input (no-auditory baseline). In contrast to the current study, the visual stimuli consisted of single objects and the visual stimuli were presented continuously, whereas the words and sounds were only presented at the onset of each trial, and the words and sounds were embedded in a referential context (e.g., Look at the X). While words were less likely to slow down processing of visual information compared to unfamiliar nonlinguistic sounds, consistent with the previous study, familiarity seemed to play a key role in attenuating overshadowing effects: when nonlinguistic sounds were prefamiliarized or embedded in a familiar naming context, the speed of visual processing increased. These findings not only highlight the role of familiarity in cross-modal processing, but they also show that these effects stem from auditory input affecting the processing of visual input.

While stimulus familiarity appears to play a key role in cross-modal processing, the mechanism underlying the effects of auditory input on processing of visual input will require additional research. In particular, it remains unclear whether the reported effects reflect processing of arbitrary auditory and visual pairings or the effects of dynamic input on processing of static input. Recall that in the reported studies, the auditory stimuli were dynamic (in that they had a temporal component), whereas visual stimuli were static.

Another interesting issue raised in the current study is the finding that prefamiliarized sounds facilitated visual processing, whereas unfamiliar labels simply did not interfere with visual processing. These findings question whether the effects of labels and prefamiliarized sounds stem from the same underlying mechanism (i.e., increased familiarity) or from two different mechanisms. We believe that this differential effect can be accounted for by distinguishing between item familiarity and class familiarity. Recall that the prefamiliarized nonlinguistic sounds were familiar at the onset of the experiment proper in Experiment 2A, whereas the specific labels presented in Experiment 1A were novel ("vika" and "kuna"). While speculative at this point, it is possible that familiar items elicit stronger effects than unfamiliar items from a familiar class of stimuli. However, additional support for the claim that familiarity can account for some of the effects of labels is the finding that prefamiliarized labels (e.g., Robinson & Sloutsky, 2004b) and prefamiliarized sounds (i.e., the current study) have comparable effects on visual processing. While it is clear that additional research is needed, the current findings raise the possibility that some of the effects of labels may stem from low-level factors such as stimulus familiarity.

Taken together, the findings reported here suggest that some of the effects of words stem from general-auditory factors affecting allocation of attention in the course of cross-modal processing. How do the general-auditory factors contribute to the effects of words across points of development? There are several possible mechanisms underlying these effects. First, it is possible that general-auditory factors, linguistic factors, and communication factors all contribute independently to the effects of words. A stronger variant is that the general-auditory factors underlie the development of language-specific and communication effects. In particular, familiarity with human speech may give linguistic input a leg-up on other types of auditory stimuli, which in turn may help children acquire the notion that words but not sounds refer to objects and categories. An even stronger (and possibly the strongest) version may be that many if not all of the reported linguistic effects found in infancy and early childhood actually stem from general-auditory factors. Fleshing out these mechanisms and distinguishing among them on the basis of empirical evidence is an important goal for future research.

7.5. Conclusion

Several novel findings stem from the research reported here. First, similar to unfamiliar sounds, unfamiliar linguistic labels overshadow corresponding visual stimuli in 10-month-olds, whereas by 16 months of age children were more likely to encode a visual stimulus when it was accompanied by a label. Second, prefamiliarization with sounds resulted in tuning effects in 16-month-olds—elevated processing of corresponding visual input. And finally, the reported tuning effects cannot be explained by poor processing of the prefamiliarized auditory input: prefamiliarization with auditory input did not affect auditory processing, whereas it did affect visual processing. Taken together, these results suggest that some effects of labels stem from attentional factors which may not be specific to language.

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