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The effect of stimulus familiarity on modality dominance

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Abstract

When unfamiliar non-speech sounds and visual input co-occur, they often compete for attention, with auditory input overshadowing visual information for infants and young children(Robinson & Sloutsky, in press; Sloutsky & Napolitano, 2003). The current study investigated whether labels and familiar sounds also compete for attention with corresponding visual information in infancy. The results indicate that, unlike unfamiliar, non-speech sounds, labels do not compete for attention with corresponding visual information at 16-months of age: 16-month-olds ably encoded both auditory and visual information. At the same time 8-month-olds only encoded the labels. When infants were familiarized to the same non-speech sounds that overshadowed visual input in Robinson and Sloutsky's study, 16-month-olds encoded both auditory and visual information, whereas, 8-month-olds continued to encode only the sounds. These findings in conjunction with Robinson and Sloutsk (in press) and Sloutsky and Napolitano (2003) findings point to important developmental progression in processing of auditory and visual infromation.

Introduction

Language plays an important role in conceptual development. When two entities share a common label, children are more likely to perceive these entities as being more similar to each other (Sloutsky & Lo, 1999), more likely to group these entities together (Sloutsky, Lo, & Fisher, 2001), and more likely to make inferences from one entity to the other (Gelman & Markman, 1986; Sloutsky, et al., 2001).

The effect of linguistic input on categorization appears very early in development. Even 8- and 9-months-olds were purported to benefit from linguistic input when forming object categories (Balaban & Waxman, 1997). In particular, it has been argued that "…from the onset of acquisition, object naming and object categorization are linked. Infants across the world begin the task of word learning equipped with a broad, universal expectation that directs them to link novel words to commonalities among objects." (Waxman, 2003, p. 213).

For example, in Balaban and Waxman's (1997) study, 9-month-olds who heard labels or content-filtered speech (which retained the original prosodic pattern) were more likely to categorize entities at the basic-level than children who only heard sounds. Therefore, it appears that hearing the same linguistic input associated with different exemplars helps infants group these exemplars together. Labels can also help infants detect differences between objects (Xu, 2002). Here, 9-month-olds are more likely to differentiate two objects when the two objects are associated with different labels. Thus, hearing the same label associated with different exemplars helps infants group these objects together, and hearing different labels helps infants differentiate the objects.

Various mechanisms have been proposed in an attempt to explain the importance of linguistic input on conceptual development. Language-specific explanations suggest that children understand that entities belong to categories, and labels highlight categories (Gelman & Markman, 1987). Labels may also be weighed heavier than other features such as appearance because children may be attentive to the prosody of human speech (Balaban & Waxman, 1997). From a general-auditory explanation, labels may initially be weighed heavier than other features because labels are presented to the auditory modality. Moreover, auditory information receives privileged processing early in development (Robinson & Sloutsky, in press; Sloutsky & Napolitano, 2003).

In support of a general-auditory explanation, Sloutsky and Napolitano (2003) demonstrated that modality preference changes throughout development: Four-year-olds are more likely to attend to auditory input, whereas adults are more likely to attend to visual input. This finding suggests that the greater attention to auditory information may explain, in part, the effects of labels.

More recently, Robinson and Sloutsky (in press) extended these findings with infants as young as 8-months of age. Here, infants were familiarized to an auditory-visual compound stimulus ($AUD_{old}VIS_{old}$). After familiarization, infants were presented with four different test trials ($AUD_{old}VIS_{old}$ and $AUD_{new}VIS_{new}$), which served as within subjects controls and ($AUD_{new}VIS_{old}$ and $AUD_{old}VIS_{new}$), which were used to determine if infants were primarily attending to auditory, visual, or both auditory and visual components during familiarization. If infants attend to a specific component during familiarization, looking should increase when that component changes at test. In sum, infants increased looking when either the auditory component or both components changed ($AUD_{new}VIS_{old}$ and $AUD_{new}VIS_{new}$); however, infants at 8-, 12, and 16-months of age did not increase looking when only the visual component changed ($AUD_{old}VIS_{new}$). This finding suggests that infants were primarily attending to the auditory input during familiarization. At the same time, infants amply encoded the visual component when it was presented in isolation, which suggests that the auditory component overshadowed the visual component.

These results point to auditory dominance early in development and they have several important implications. Most importantly, auditory dominance effects can provide a coherent account for many of the previous findings. Recall that it has been argued that common labels help infants detect commonalities between objects, and different labels help children differentiate objects. Although infants in Robinson and Sloutsky (in press) study were presented with non-speech sounds, the pattern of results look identical to what would be expected if infants were presented with linguistic labels (i.e., the same visual stimulus that was presented during familiarization was perceived as new when paired with a new sound and a new visual stimulus was perceived as old when paired with the old sound). In short, it seems possible that under both speech and non-speech auditory input conditions, infants rely primarily on the auditory information.

The aim of Experiment 1 was to test this hypothesis by investigating whether linguistic labels, similar to the non-speech sounds (Robinson & Sloutsky, in press), overshadow visual input. In particular, if linguistic input is weighed heavier than visual input because it represents auditory information then non-speech sounds and labels should reveal similar patterns of results.

Experiment 1

Method

Participants Nineteen 8-month-olds (5 boys and 14 girls, *M* = 249 days, *Range* = 231 - 280 days) and nineteen 16-month-olds (6 boys and 13 girls, *M* = 489 days, *Range* = 470 - 501 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., > 2500g birth weight) with no auditory or visual deficits, as reported by parents. A majority of infants were Caucasian. Data provided by 7 infants were not included due to fussiness, and 10 infants were excluded because they did not reach the training criterion indicated below.

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

Stimuli Each infant was familiarized to an auditory-visual compound stimulus ($AUd_{old}VIS_{old}$) and tested on four auditory/visual combinations ($AUD_{new}VIS_{old}$, $AUD_{old}VIS_{new}$, $AUD_{new}VIS_{new}$, and $AUD_{old}VIS_{old}$). The auditory components consisted of two infant-directed nonsense labels (vika and kuna), which were presented at 65-68 dB. The visual components consisted of two three-shape patterns (circle, pentagon, triangle, and cross, octagon, square), and were projected to 25 cm x 7 cm in size. Previous research has demonstrated that infants can discriminate these visual stimuli when presented in isolation; however, they are overshadowed by unfamiliar non-speech sounds (Robinson & Sloutsky, in press; Experiment 2).

Procedure The procedure consisted of 10 familiarization trials, 2 test trials, 3 retraining trials, and 2 more test trials. Each familiarization trial consisted of a compound stimulus that appeared for 1000 ms and disappeared for 500 ms. Each stimulus appeared five times during each trial (7500 ms trial duration). After familiarization, infants were present with 4 different test trials ($AUD_{new}VIS_{old}$, $AUD_{old}VIS_{new}$, $AUD_{new}VIS_{new}$, and $AUD_{old}VIS_{old}$). Test trials were 12 s in duration and were randomized so that each test stimulus had an equally likely chance of appearing as the first test trial, last test trial, etc. The retraining trials were the same as familiarization trials and were used to remind infants of the familiarization stimulus. Retraining trials always appeared between the first two and last two test trials. Fixations were recorded online by an experimenter for all training, test, and retraining trials. A random sample of 25% of the infants were coded offline by experimenters who were blind to the auditory and visual components presented to infants. No differences were found between subjects coded on- and offline.

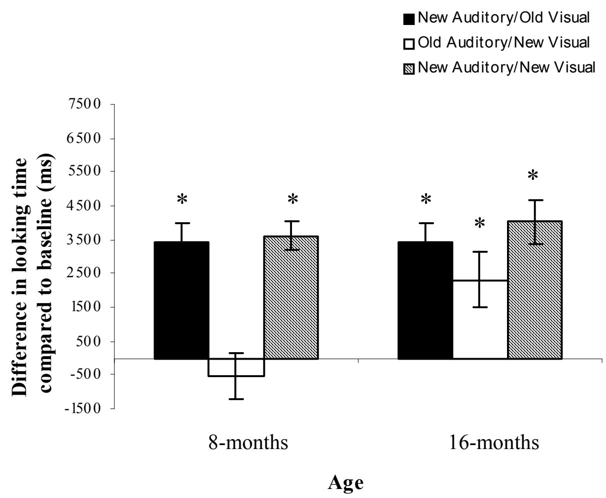
Results and Discussion

Training Criterion. Only infants who demonstrated a novelty preference at test were included in additional analyses (i.e., looking to $AUD_{new}VIS_{new} > AUD_{old}VIS_{old}$). As reported above, 10 infants did not reach this criterion.

Test Trials. Analysis of test trials focused on whether infants were primarily attending to auditory and/or visual input during familiarization. A difference score was calculated by taking the accumulated looking to each test stimulus and subtracting it from baseline (e.g., the effect of changing the auditory component = $AUD_{new}VIS_{old} - AUD_{old}VIS_{old}$). Thus, positive numbers indicate that looking increased as a function of changing a specific stimulus component, which suggests that infants encoded that modality during training. As can be seen in Figure 1, at 8- and 16-months of age, looking increased when the auditory component changed and when both auditory and visual components changed, one-sample *t*s > 0, *t*s > 5, *p*s < .001. In contrast, only the 16-month-olds increased looking when the visual stimulus changed, one-sample $t > 0$, $t\,(18) = 2.88$, $p < .01$.

A 2 (Age: 8-months, 16-months) x 3 (Test Trial: $AUD_{new}VIS_{old}$, $AUD_{old}VIS_{new}$, $AUD_{new}VIS_{new}$) revealed an effect of Test Trial and also confirmed the Age x Test Trial interaction, *F*s > 5, *p*s < .01. At 8-months of age, changing the auditory component had a larger effect than changing the visual component, $DIFF_{AUDnewVISold} = 3435$ ms > $DIFF_{AUDoldVISnew} = -552$ ms, paired $t\,(18) = 5.87$, $p < .0001$. This difference, however, attenuated at 16-months of age ($DIFF_{AUDnewVISold} = 3403$ ms = $DIFF_{AUDoldVISnew} = 2318$ ms), paired $t\,(18) = 1.40$, $p > .1$.

Figure 1. Effects of changing labels and visual stimuli in Experiment 1



Note: *Difference score > 0, *p* < .01. Error bars represent standard errors.

It is important to note that, although the nonsense labels overshadowed visual input at 8 months of age, these same visual stimuli were ably encoded by 8-months-olds when presented in isolation (Robinson & Sloutsky, in press). In contrast, 16-month-olds encoded both the auditory and visual components. This pattern of results is strikingly different from those reported by Robinson & Sloutsky. In particular, when the same visual stimuli were paired with unfamiliar non-speech sounds (laser and static sounds), 8- , 12-, and 16-month-olds only encoded the auditory component. Thus, the results from the current experiment, in conjunction with Robinson & Sloutsky, demonstrate that both speech and non-speech auditory input overshadow visual input at 8-months of age. In contrast, by 16-months of age children encode both auditory and visual components; however, only when the auditory input consists of speech sounds. While revealing interesting developmental differences in effects of label on processing of visual information, the current study did not elucidate the nature of these effects.

Experiment 2

The goal of Experiment 2 was to determine whether the effect of label stems from language-specific properties or from general-attentional effects. From a language-specific perspective, the different pattern of results at 16-months of age between Experiment 1 with those reported in Robinson & Sloutsky (in press) could stem from privileged processing of linguistic input. In particular, it is possible that linguistic information does not compete for attention with corresponding visual information, which allowed 16-month-olds to process both auditory and visual information. However, it is also possible that human speech represents a familiar class, and even familiar non-speech sounds do not compete for attention with corresponding visual input. Although very few empirical studies, if any, have compared processing of familiar sounds with linguistic input early in development, there is preliminary neurophysiological evidence with adults suggesting that familiar non-speech sounds are processed in the brain similarly to words (Cycowicz & Friedman, 1998). Thus, the goal of Experiment 2 is to determine if stimulus familiarity can account for differences between Experiment 1 and Robinson & Sloutsky (in press).

Method

Participants Twenty 8-month-olds (10 boys and 10 girls, M = 252 days, *Range* = 245 - 269 days) and ten 16-month-olds (4 boys and 6 girls, M = 490 days, *Range* = 474 - 504 days) participated in this experiment. Recruitment procedures and demographics were identical to Experiment 1. Data provided by 2 infants were not included due to fussiness, and 13 infants were excluded because they did not demonstrate a novelty preference (i.e., $AUD_{new}VIS_{new} > AUD_{old}VIS_{old}$).

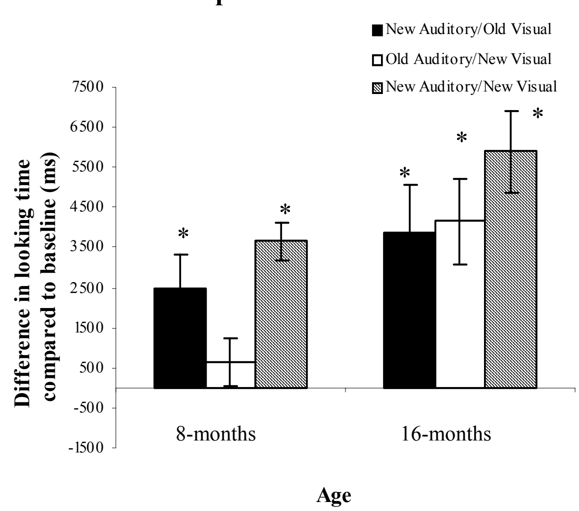
Stimuli and Procedure With two exceptions, the procedure was identical to Experiment 1. First, the nonsense labels were replaced with non-speech sounds (laser sound and static sound). Note that these same sounds overshadowed the three-shape patterns in Robinson & Sloutsky (in press). Second, and most importantly, children were familiarized to the non-speech sounds prior to the actual experiment. In the current experiment children sat on parent's laps and heard each non-speech sound 10 different times. As with the actual experiment, the auditory stimulus was presented at 65-68 dB, and each auditory stimulus lasted for 1000 ms. Auditory stimuli were presented in pairs and pseudorandomized so that infants heard the same stimulus at least twice in a row and no more than 4 times in row. In addition, the non-speech sounds were not associated with the three-shape patterns or any visual stimulus. This ensured that children in Experiments 1 and 2, and children in Robinson & Sloutsky (in press) all had equal experience with the three-shape patterns. After infants heard each sound 10 times, infants were given a 4 minute distracter task in which they looked at realistic pictures of animals. After the distracter task, infants were then presented with the main experiment.

Results and Discussion

As in Experiment 1, a difference score was calculated by taking the accumulated looking to each test stimulus and subtracting it from baseline. As can be seen in Figure 2, the pattern of results are very similar to Experiment 1. That is, both age groups increased looking when either the auditory component changed or when both auditory and visual components changed, one-sample ts > 0, ts > 3, ps < .01, and only the 16-month-olds increased looking when the visual stimulus changed, one-sample $t > 0$, $t(9) = 3.86$, $p < .01$.

A 2 (Age: 8-months, 16-months) x 3 (Test Trial: $AUD_{new}VIS_{old}$, $AUD_{old}VIS_{new}$, $AUD_{new}VIS_{new}$) revealed an effect of Test Trial, $F(2, 56) = 7.72$, $p < .001$. Here, children looked longer when both components changed ($DIFF_{AUDnewVISnew}$ = 4401 ms) than when only the auditory component changed ($DIFF_{AUDnewVISold}$ = 2940 ms) or when only the visual component changed ($DIFF_{AUDoldVISnew}$ = 1819 ms), paired ts > 2.5, $p < .01$. The above analyses also revealed an effect of Age, $F(1, 28) = 5.93$, $p < .05$, with 16-month-olds (M = 4631 ms) accumulating more looking across test trials than 8-month-olds (M = 2264 ms).

Figure 2. Effects of changing familiar sounds and visual stimuli in Experiment 2



Note: *Difference score > 0, $p < .01$. Error bars represent standard errors.

General Discussion

The results from the two experiments in conjunction with Robinson & Sloutsky (in press) demonstrate that unfamiliar non-speech sounds, familiar non-speech sounds, and nonsense labels all overshadow visual input at 8-months of age. That is, 8-month-olds do not discriminate visual stimuli when these images are paired with auditory input; however, they ably discriminate the same images when presented in isolation (Robinson & Sloutsky, in press). In contrast, 16-month-olds encode both the auditory and visual components; however, only when the visual stimuli are paired with labels or familiar sounds. Interestingly, the non-speech sounds that children heard in Experiment 2 were the same non-speech sounds that overshadowed the three-shape patterns in Robinson and Sloutsky's study. These findings demonstrate that, at 16-months of age, just hearing an auditory stimulus a few times affects the way children attend to auditory and visual input. These findings also demonstrate that familiar sounds and labels have similar effects on processing of auditory and visual information at 8- and 16-months of age.

Overall, the current study expands previous research concerning the development of attention, the role of familiarity in the auditory modality, and possible mechanisms underlying the effect of labels on conceptual development.

One potential explanation of the developmental differences found in the current study concerns the notion that attentional biases and attentional resources change considerably throughout development. There is a growing body of research demonstrating that younger children are more likely than adults to demonstrate a preference for auditory input and more likely to encode only one modality (Robinson & Sloutsky, in press; Sloutsky & Napolitano, 2003). Currently, there are several possible mechanisms that may explain this developmental pattern. First, it is possible that young children lack attentional resources that are needed for simultaneously processing auditory and visual input. However, it is also possible that young children either habituate to and/or process auditory information faster than visual information. Future research will need to address this issue.

The current study also introduces the notion that familiar sounds and labels may play a similar role early in development. Although there is neurophysiological work demonstrating that familiar sounds are processed in the brain similarly to words (Cycowicz & Friedman, 1998), the current study provides behavioral evidence for this notion in infancy. One interesting question concerns the idea that labels may represent a familiar class of auditory stimuli. This would explain why labels and familiar sounds have similar effects in the adult brain, as well as in the current study.

At a more general level, it is well known that linguistic input plays a large role in conceptual development. However, it is uncertain how and when labels become special. Even as young as 9-months of age, hearing the same label associated with different exemplars helps infants group these objects together, and hearing different labels helps infants differentiate objects (Balaban & Waxman, 1997; Xu, 2002). Interestingly, 8-month-olds in the current study demonstrated the same pattern of results when presented with unfamiliar non-speech sounds (Robinson & Sloutsky, in press), labels, and familiar sounds. This suggests that young children may initially rely on various types of auditory information (sounds and labels), and this initial preference for auditory input may help bootstrap labels into a special status.

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