Modality preference and its change in the course of development

Amanda C. Napolitano (napolitano.7@osu.edu)
Department of Psychology
Ohio State University
48 Townshend Hall, 1885 Neil Avenue
Columbus, OH 43210, USA

Vladimir M. Sloutsky (sloutsky.1@osu.edu)
Center for Cognitive Science & School of Teaching & Learning
Ohio State University
21 Page Hall,1810 College Road
Columbus, OH 43210, USA

Sarah T. Boysen (boysen.1@osu.edu)
Department of Psychology
Ohio State University
48 Townshend Hall, 1885 Neil Avenue
Columbus, OH 43210, USA

Abstract

The current study examines the modality preference and its change in the course of development. Based on findings from previous research (Balaban & Waxman, 1997; Roberts, 1995; Sloutsky & Lo, 1999), it was expected that the auditory modality would be privileged at a very young age. In the experiment, participants after being trained to select a target image and sound combination were required to select a new combination where the target image was paired with a new sound and the target sound was paired with a new image. It was argued that the selected set would be indicative of whether the image or sound is more salient. Results indicate that the auditory modality was more salient than visual for 4-year-olds, whereas the visual modality was more salient for 5-year-olds and adults.

Introduction

It is well known that linguistic labels play an important role in induction. For example, in Gelman & Markman's (1986) forced-choice task, young children were presented with pictures of a blackbird (Target), flamingo (Test 1), and bat (Test 2) that was perceptually similar to the blackbird. Both the blackbird and flamingo were referred to as "birds," and the task was to induce a property (e.g., "feeds its young with mashed food" vs. "feeds its young with hard food") from one of the Test stimuli to the Target. Results indicated that young children reliably induced biological properties from one bird to another bird, even when both birds were perceptually dissimilar. Other researchers demonstrated large, albeit quantitative, effects of labels using a variety of stimuli and tasks (Sloutsky & Lo, 1999; 2000; Sloutsky, Lo, & Fisher, in press). There are also findings that in categorization tasks linguistic labels supported taxonomical grouping of objects in infants (Balaban & Waxman, 1997; Waxman & Markow, 1995) and in young children (Markman, 1989).

These findings have generated three primary explanations: semantic, phonetic, and general-auditory. The two former explanations argue for specific linguistic effects of labels, whereas the third argues for more general auditory effects.

The semantic explanation (Gelman & Markman, 1986; Markman, 1989) has focused primarily on explaining the effects of labels on induction in young preschool-age children. It has been argued that linguistic labels presented as count nouns denote categories, and, because members of the same category are likely to share many nonobvious properties (two cows are more likely to have similar insides than a cow and a pig) shared linguistic labels support induction.

The phonetic explanation (Balaban & Waxman, 1997) has focused on explaining categorization in young infants. According to this position, young infants are especially attentive to the prosodic components of human speech that distinguish it from other sounds (Balaban & Waxman, 1997, Experiment 3). As a result, when presented with pictures accompanied by auditorily introduced labels, infants attended to linguistic labels and to visual features that correlated with linguistic labels.

Finally, the general auditory explanation suggests that, at least for infants and very young children, the effects of labels may stem from the modality of input (Sloutsky & Lo, 1999). In particular, it is possible that the powerful effects linguistic labels have on categorization and induction are due to the fact that auditory input has a privileged processing and attentional status in younger humans (cf. Roberts, 1995; Roberts & Jacob, 1991). If this is the case, stimuli presented auditorily should have larger attentional weights than stimuli presented in another modality.

Why would auditorily presented stimuli weigh more for younger children than visual stimuli? One possible explanation is that the auditory system matures earlier than the visual system: in particular, the auditory system starts functioning during the last trimester of gestation (Birnholz & Benaceraff, 1983; see also Jusczyk, 1998, for a review), whereas the visual system does not start functioning until after birth. As a result, even though the neural bases of visual perception are fully developed at quite a young age (e.g., Aslin & Smith, 1988), auditory stimuli may still have a privileged processing status for younger children, thus resulting in larger weights of auditory stimuli. This privileged status of the auditory modality may be functionally important for language acquisition, and, in this case the advantage may start decreasing when the child has (in principle) acquired the task of acquiring language.

The goal of current research is to test this general auditory explanation. Note that support of the general auditory explanation does not rule out the semantic and the phonetic explanations. Because the three explanations are not mutually exclusive, it is possible that linguistic labels may have semantic and phonetic effects above and beyond the general auditory effect.

The overall experimental approach was as follows. Participants were presented with two stimulus sets each consisting of an auditory and a visual component and were trained to consistently select one set over the other. When training was accomplished, they moved to a test phase, in which the trained set was split, such that the visual stimulus of the trained set was paired with a novel auditory stimulus, whereas the trained auditory stimulus was paired with a novel visual stimulus. The participants were asked which of the two was the trained set. It was argued that if participants put more weight on the visual stimulus, they should select the first set, whereas if they put more weight on the auditory stimulus they should select the second one.

Method

Participants

A total of 39 children and undergraduate students participated in the experiment. Participants represented three age groups with 13 participants in each group: (1) 48-month-olds to 57-month-olds, (2) 58-month-olds to 65-month-olds, and (3) undergraduate students at The Ohio State University. The second group was added when the experiment was under way. This was done to provide more dense developmental observations. Children participants were recruited from local childcare centers in the Columbus, Ohio area. Undergraduate students participated as part as part of an introductory psychology course.

Materials

Materials consisted of 24 stimulus sets. Each set was comprised of a visual and an auditory stimulus. The visual stimuli were digitized photographic landscape images. Each image consisted primarily of a different type of green foliage. Images were 4 inches by 4 inches in size. The auditory stimuli were computer generated patterns, each consisting of three unique simple tones. Simple tones varied on flavor (sine, triangle, or sawtooth) and frequency (between 1 Hz and 100 Hz) components. Each simple tone was .3 seconds in duration and was separated by .05 seconds of silence, for total pattern duration of 1 second.

Diagnostics were run to insure the auditory and visual stimuli had high discriminability. This was accomplished using a same-different task. In the task participants were presented with one stimulus for a duration of one second, followed by the presentation of a second stimulus for a duration of one second, and then asked whether the two stimuli were the same. The participants were able to discriminate between all stimuli on over 95 percent of the trials.

Design and Procedure

The experiment included six blocks, each consisting of 8 training trials (a training session) and 6 test trials (a testing session). In each block, 4 out of the 24 stimulus sets were used. Two of these four sets were used in the training session, and the other two were used in the testing session. Children participants were tested in a quiet room within their daycare center. Small toys were used as rewards for participation. Undergraduate participants were tested in a lab on campus. A laptop computer controlled presentation of stimulus sets and recorded all responses. Participants entered the room and sat in a chair in front of laptop. They were told that they would play a game (references to toys were omitted for undergraduate participants), in which they should find the location of a prize. They were then presented on-screen with two stimulus sets each consisting of a visual component (V_1 vs. V_2) and an auditory component (A_1 vs. A_2).

Stimuli were presented in the following manner. First, V_1 and A_1 were presented simultaneously on one side of the screen, followed by the presentation V_2 and A_2 on the other side of the screen. Each image's presentation matched the duration of its sound, and was replaced by a white circle icon at the end of each set's presentation. In short, the child was presented with two stimuli sets V_1A_1 and V_2A_2 and the task was to identify the stimulus set, under which the prize is hidden. The goal of training was to teach the child to consistently select a particular stimulus set, and, therefore, on each trial the child was provided with yes/no feedback. The positions of each of the two stimulus sets were counterbalanced across the 8 training trials. Participants making correct selections in the final four trials moved into the test session.

The test session followed immediately after the training session, during which participants were presented with two novel stimulus sets: set one (V_1A_{new}) matched the training target's visual component, but had a novel auditory component, whereas set two ($V_{new}A_1$) had a novel visual component, but matched the training target's auditory component. The participants were asked again to identify the one where a prize was hidden. When the participant's selection was made, the experimenter pressed the keyboard key corresponding to the selection, without giving feedback to the participant. The overall structure of training and testing trials is presented in Table 1.

Table 1: The overall structure of training and testing trials.

Training Trial		Testing Trial	
V_1A_1 (Target)	V_2A_2 (Distracter)	V_1A_{new}	$V_{new}A_1$

Results and Discussion

In this section, we analyze participant's choices in the testing phase. Recall that stimulus sets were arranged such that participants could rely either on the visual components of the learned stimulus set (V_1) or on the auditory component (A_1). We first compare overall means of visual and auditory responses across the three age groups. We then report provide a more detailed analysis of participants' performance. In particular, we compare the number of blocks where participants were above chance selecting either the familiar visual or auditory component. We also analyze individual patterns of responses, comparing the number of participants consistently exhibiting auditory responding with those consistently exhibiting visual responding. Note that 48-month-olds to 57-month-olds successfully accomplished 61 out of 78 training sessions (78%), 58-month-olds to 65-month-olds successfully accomplished 65 out of 78 training sessions (84%), and adults successfully accomplished all 78 training sessions. There were also 7 children in the youngest group and 2 children in the older group who did not pass a single training session. These children were eliminated from the analyses and they are not a part of 39 participants whose data are reported here.

Overall means for auditory-based responding were subjected to a one-way ANOVA with age as a factor, followed up by post-hoc Tukey tests. The analyses indicated that these means (65% vs. 22% vs. 2%) differed significantly across the three age groups, F (2, 36) = 19.9, p < .0001, and post-hoc Tukey test confirmed that there were significant differences among the groups.

To analyze participants' performance in test sessions, we calculated the number of sessions with above-chance reliance on auditory stimuli, above chance reliance on visual stimuli, and chance performance. Performance was considered above chance if the same choice was made on 5 out of 6 trials (Binomial Test, p = .09), otherwise it was considered at chance. Results indicate that in the group of 48-57-month-olds only 9 out of 61 session were at chance, and in the group of 58-65-month-olds 10 out 65 were at chance. All other sessions were above chance. In the group of undergraduate students all test sessions were above chance. Percentages of sessions with above-chance performance by age group and stimulus modality are presented in Figure 1.

Percentages of sessions with above change auditory and responses were subjected to two separate one-way ANOVA with age as a factor. There were significant differences across age groups, both Fs (2, 36) >19, ps < .0001. The post-hoc Tukey tests pointed to the following order differences: 48-57-month-olds were more likely to rely on auditory stimuli and less likely to rely on visual stimuli than 58-65-month-olds or undergraduate students.

Across age groups, there emerged three distinct patterns of responses: (1) participants who were above chance in relying on auditory stimuli (auditory responders); (2) participants who were above chance in relying on visual stimuli (visual responders); and (3) participants who were at chance (mixed responders). Percentages of responders' types across age groups are presented in Table 2.

Table 2. Percentages of responder types by age group.

	Responder Type		
Age Group	Visual	Auditory	Mixed
48-57-month-olds	15.38	61.53	20.07
58-65-month-olds	76.92	15.38	7.69
19-year-olds	100.00	0	0

Numbers of auditory and visual responders in each age were subjected to a chi-square analysis. The analysis pointed to significant differences among the groups, both χ^2s (2, N =39) > 13.4, p < .001. The analysis of standardized residuals indicated that 48-57-month-olds were more likely to exhibit an auditory-based pattern than 58-65-month-olds or 19-year-olds, whereas 58-65-month-olds or 19-year-olds were more likely to exhibit a visual-based pattern of responses (all zs > 3.1, ps < .001).

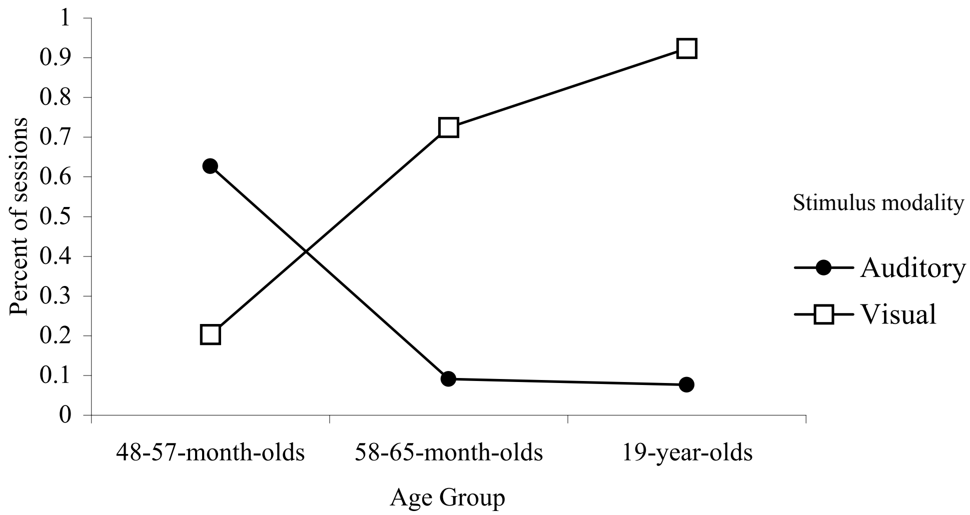

Figure 1. Percent of test seccions at above-chance performance by age group and stimulus modality

In short, the reported data indicate that for 48-57-month-olds auditorily presented stimuli weighed more than visually presented stimuli. These data support the auditory explanation predicting larger weights of auditory stimuli weights for younger children, but not for older children or adults. Of course, the support of the general auditory explanation does not rule out either the phonetic or the semantic explanations. These explanations will be further examined in our future research.

There is also a possible alternative explanation for the significant differences between 48-57-month-olds and the two other groups. First, the younger children's selections may be due to differential complexity of the stimuli. Each auditory stimulus contains far fewer features as compared with the visual stimuli, and, for this reason, the auditory stimuli are simpler to encode and process. Therefore, it is possible that children in the youngest group prefer simpler stimuli that happened to be auditorily presented, rather than prefer auditory stimuli per se. Of course, this explanation would have a hard time explaining the sudden shift from the larger weight of auditory stimuli observed in 48-57-month-olds to the larger weight of visual stimuli observed in 58-65-month-olds, however our current hypothesis also does not have an acceptable explanation for the shift. As mentioned above, there are two possible reasons for audition having priority at a young age. The auditory modality is functional before birth, and it is clear that at birth it is the dominant modality. Perhaps, it is not until the late 4's that the visual modality gains its privileged status. The privileged status of audition may also be related to language acquisition. It is possible, that the auditory modality is privileged during the period where a child's vocabulary acquisition is at its highest. In both cases, our experiments are likely to capture the very end of the period when auditory modality is privileged and the transition to the privileged status of the visual modality. To clarify this issue additional experiments with young infants are needed.

In future research, we plan to examine the above mentioned alternative explanations suggesting that the observed results stem from different computational complexity of stimuli, with impoverished auditory patterns being more simple than more rich and elaborated visual scenes. The next phase of the study will be to reverse the complexity of the stimuli and present participants with impoverished visual stimuli and complex elaborated auditory stimuli. The visual stimuli will be computer-generated two-dimensional geometric figures. The auditory stimuli will be compressed pieces of Celtic music. If the 48-57-month-old group continues to make selections that favor audition, this will provide evidence for the privileged status of auditory processing for young children. If the 48-57-month-olds' selections favor visual stimuli, this will instead provide evidence that young children use stimulus information that is easier to process.

Following this second experiment, it will be useful to examine whether introducing human speech has any effect on the percentage of auditory selections. In this experiment, sounds will be comprised of three phonemes (e.g. "ba te do"). The results of this experimentation, considered with the results from experiment one, should elicit the attentional weights given to language-rich and auditory stimuli in general.

Finally, it will be necessary to test younger children and infants to determine if preference for auditory stimuli decreases monotonically with age. It is possible that the relation is an inverted U-type, and the auditory modality only becomes dominant during the "explosion" period of language development.

While these alternatives will be tested in the future, research presented here indicates that under these conditions, auditory stimuli weigh more than visual stimuli for 48-57-month-olds, whereas visual stimuli weigh more than auditory for older children and adults. These results support the hypothesis that for young children auditory input may have privileged processing status.

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