

**MODALITY DOMINANCE IN YOUNG CHILDREN:
UNDERLYING MECHANISMS AND BROADER IMPLICATIONS**

DISSERTATION

Presented in Partial Fulfillment of the Requirements for the
Degree Doctor of Philosophy in the Graduate School of
The Ohio State University

By

Amanda C. Napolitano

The Ohio State University

2006

Dissertation Committee:

Professor Vladimir Sloutsky, Adviser

Professor John Opfer

Professor Laura Wagner

Approved by

Adviser

Graduate Program in Psychology

ABSTRACT

Previous research established that early in development, processing of arbitrarily paired auditory-visual stimuli often results in modality dominance effects, with young children processing one modality while failing to process the other modality (Sloutsky & Napolitano, 2003; Napolitano & Sloutsky, 2003; Robinson & Sloutsky, 2004). These modality dominance effects are important for understanding the development of auditory and visual processing and attention, and they may have broader implications for understanding some critical aspects of interrelations between language and cognitive development. To address these issues, the current research examines: 1) the factors underlying modality dominance, 2) the role of attention in modality dominance, 3) and the role of modality dominance effects in categorization. In the first set of experiments (Chapter 2), 4-year-olds were presented with auditory/visual compounds, in which (a) the familiarity of auditory stimuli relative to visual stimuli was systematically varied (Experiments 1-2) and (b) auditory stimuli became more language-like (Experiments 3-4). The results indicated that auditory dominance is a special case of flexible modality dominance, mediated by the relative familiarity of stimuli, and that the effects produced by linguistic stimuli may be explained by auditory and familiarity factors. The second set of experiments (Chapter 3) examined the attentional mechanism underlying modality dominance, by (a) mixing trials or blocks of trials that produce visual and auditory

dominance (Experiments 5-7), and (b) giving explicit instructions to ignore the dominant modality (Experiments 8-9). The results indicated that young children can switch from visual to auditory dominance, but experience difficulty switching from auditory to visual dominance. Furthermore, when given instructions to ignore a dominant modality, young children were able to ignore dominant visual input, but were unable to ignore dominant auditory input, unless instructions to ignore the dominant auditory input were repeated on every trial. The final set of experiments (Chapter 4) explored whether modality dominance alone could explain the effects of labels by presenting 4-year-olds with a forced-choice categorization task that pit shared picture against shared sound, where sounds were nonsense count nouns, vowel patterns, familiar machine sounds, or tone patterns. Results indicated that when pictures are accompanied by nonsense count nouns, young children are less likely to use perceptual similarity to categorize the pictures, and that the effects of auditory input did not differ when either vowel patterns or familiar machine sounds (Experiments 11-13) were substituted for the count nouns. Furthermore, the results indicated the effects of sounds do not stem from young children being unable to ignore task irrelevant information, as there were no observed effects for sounds when unfamiliar tone patterns (Experiment 14) were substituted for count nouns. In sum, findings presented in the three phases of research support the attentional account of modality dominance and suggest that the effects of linguistic labels in categorization may stem in part from modality dominance effects.

To my husband Frank and daughter Isabella

ACKNOWLEDGMENTS

I would like to express my deepest gratitude to my adviser, Dr. Vladimir Sloutsky. His guidance and support, as well as limitless brilliant ideas, made this research possible. He has been a wonderful mentor and friend, and is a true intellectual Superhero.

I thank Dr. John Opfer for his brilliance and support. I am very grateful for his insightful comments and for the alternative viewpoint he provided, as his input helped shape this research.

I also thank Laura Wagner for her brilliance and support. I am very grateful for her willingness to come in on the final stages of this research and for her fabulous input that helped shape this research.

I thank my previous undergraduate advisors Dr. Gary Greenberg and Emily Weiss and masters thesis advisor Dr. Sarah Boysen for the wonderful opportunities that they provided me, for which I will always cherish.

I thank all members of our research associate team, past and present, especially Tia Foster, Marie Elam, Meredith Williams, Rachel Zufall, and Kelsy Parsons for helping to collect the data presented in this thesis.

I thank all members of the Cognitive Development lab, past and present, especially Dr. Aaron Yarlas, Dr. Chris Robinson, Dr. Heidi Kloos, Dr. Julie Hupp, Dr. Anna Fisher, Jennifer Kaminski, Margie Spino, and Sravani Vinapamula.

I thank colleagues from the Chimpanzee lab, Karen Hallberg, Dr. Valerie Kuhlmeier, Kimberly Mukobi, and all my chimpanzee friends Darrell, Keeli, Harper, Emma, Sheba, Sarah, Bobby, Kermit, Digger, Abby, and Ivy, whom I will never forget.

I thank my partner in crime through the graduate process, Dr. Becca Grime.

Last but certainly not least, I thank my family for loving and believing in me. I especially thank my daughter, Izzie, and husband, Frank, who in my moments of stress, always remind me what is truly important in life. I also single out my wonderful mother, Kathleen, and wonderful mother-in-law, Sue, for taking time out of their busy lives to baby-sit, which gave me time to write.

VITA

August 10, 1976..... Born- Russell, Kansas, USA

1998-1999..... Research Assistant, Sedgwick County Zoo

July 1, 1999..... B.A. Psychology, Wichita State University

1999-2003..... Graduate Research Associate, The Chimpanzee
Center, The Ohio State University

2000-2003..... Graduate Teaching Associate, Department of
Psychology, The Ohio State University

2001-2006..... Graduate Research Associate, The Center for
Cognitive Science, The Ohio State University

January 3, 2002..... M.A. Psychology, The Ohio State University

PUBLICATIONS

Research Publication

1. Napolitano, A. C., Sloutsky, V., & Boysen, S. T. (2001). Modality preference in induction. In R. Alterman & D. Kirsh (Eds.), *Proceedings of the XXIII Annual Conference of the Cognitive Science Society* (pp. 671-678). Mahwah, NJ: Erlbaum.
2. Sloutsky, V. M., & Napolitano, A. C. (2003). Is a picture worth a thousand words? Preference for auditory modality in young children. *Child Development*, 74, 822-833.
3. Napolitano, A. C., & Sloutsky, V. M. (2003). Flexible attention and modality preference in young children. In R. Alterman & D. Kirsh (Eds.), *Proceedings of the XXV Annual Conference of the Cognitive Science Society* (pp. 846-850). Mahwah, NJ: Erlbaum.

4. Napolitano, A. C., & Sloutsky, V. M. (2004). Is a picture worth a thousand words? The flexible nature of modality dominance in young children. *Child Development*, 75, 1850-1870.

FIELDS OF STUDY

Major Field: Psychology

TABLE OF CONTENTS

ABSTRACT	ii
ACKNOWLEDGMENTS	v
VITA	vii
LIST OF FIGURES	x
INTRODUCTION	1
CHAPTER 1: LITERATURE REVIEW	5
CHAPTER 2: THE EFFECTS OF MANIPULATIONS OF AUDITORY INPUT ON MODALITY DOMINANCE IN YOUNG CHILDREN	29
CHAPTER 3: THE ROLE OF AUTOMATIC AND DELIBERATE ATTENTION IN MODALITY DOMINANCE IN YOUNG CHILDREN	53
CHAPTER 4: MODALITY DOMINANCE EFFECTS IN CATEGORIZATION	86
CHAPTER 5: GENERAL DISCUSSION	113
BIBLIOGRAPHY	125

LIST OF FIGURES

Figure	Page
1	Examples of stimulus sets used in Sloutsky and Napolitano (2003)..... 8
2	Examples of stimulus sets used in Napolitano and Sloutsky (2003)..... 11
3	Examples of stimulus sets for Experiment 1..... 34
4	Proportions of correct same/different responses in Experiment 1. Error bars represent standard errors of the mean. Note: ** -- above chance, $p < .02$; ++ -- below chance, $p < .02$; * -- marginally above chance, $p < .07$ 37
5	Example of stimulus sets for Experiment 2..... 40
6	Example of picture choices for a trial in familiarity control task for Experiment 3..... 44
7	Proportions of correct same/different responses in Experiment 3. Error bars represent standard errors of the mean. Note: ** -- above chance, $p < .01$; ++ -- below chance, $p < .01$ 45
8	Proportion of Correct Responses in the Visual Dominance Condition in Experiment 5..... 62
9	Proportion of Correct Responses in the Auditory Dominance Condition in Experiment 5..... 63
10	Example of possible first 4 trials for Experiment 6A..... 66
11	Proportion of Auditory and Visual Processing in the Auditory and Visual Dominance Trials in Experiment 6A..... 67
12	Proportion of Auditory and Visual Processing in the Auditory Dominance First and Visual Dominance First Conditions in Experiment 7..... 74

13	Proportion of Auditory and Visual Processing in the Auditory and Visual Dominance Conditions in Experiment 8.....	78
14	Proportion of Auditory and Visual Processing in the Auditory and Visual Dominance Conditions in Experiment 9.....	81
15	Processing of Visual Information (i.e., Proportions of Hits and False Alarms) Under the Instructions to Ignore Auditory Information and in the Unimodal Visual Baseline in Experiment 9.....	83
16	Processing of Auditory Information (i.e., Proportions of Hits and False Alarms) Under the Instructions to Ignore Visual Information and in the Unimodal Auditory Baseline in Experiment 9.....	83
17	An example of the stimulus sets used in a Conflict Trial for the Sounds Presented Condition for Experiment 10.....	91
18	An example of the stimulus sets used in No Conflict Trial the Sounds Presented Condition for Experiment 10.....	91
19	Percentage of Test Item A responses in Experiment 10.....	94
20	Percentage of Test Item A responses in Experiment 11.....	98
21	Percentage of Test Item A responses in Experiment 12.....	101
22	Percentage of Test Item A responses in Experiment 13.....	105
23	Percentage of Test Item A responses in Experiment 14.....	109

INTRODUCTION

It appears that as early as 9 months of age, infants are capable of mapping familiar labels onto familiar objects (Fenson, Dale, Reznick, Bates, Thal, & Pethick, 1994). This process of labeling progresses rapidly, such that even very young children hear sounds and automatically know the objects they refer to (Jusczyk, 1998). Furthermore, the importance of labels goes beyond object reference, as labels also play a crucial role in how we think about objects. For example, when two perceptually different objects are both referred to as birds, young children are more likely to perceive the two objects as similar, group these entities, and infer non-obvious properties from one entity to another (e.g., Gelman & Markman, 1986; Sloutsky & Fisher, 2004; Sloutsky & Lo, 1999; Welder & Graham, 2001). Because labeling objects typically requires the cross-modal processing of arbitrarily paired visual and auditory information, insights into this type of processing could help to explain how children learn labels and why they utilize them.

Research has repeatedly demonstrated that efficient cross-modal processing appears relatively late in development. For example, presenting infants and young children with arbitrary auditory-visual pairings for a short duration results in cross-modal interference effects (e.g., Lewkowicz, 1988a; Lewkowicz, 1988b; Napolitano & Sloutsky, 2003; Robinson & Sloutsky, 2004; Sloutsky & Napolitano, 2003). Specifically, this research suggests that for young children, when auditory and visual input were both unfamiliar,

auditory information often interfered with processing visual information, even though the visual information was ably processed in a unimodal baseline, whereas when visual input was more familiar than auditory input, visual information often interfered with processing auditory information, even though the auditory information was ably processed in a unimodal baseline (Napolitano & Sloutsky, 2003; Robinson & Sloutsky, 2004; Sloutsky & Napolitano, 2003). These modality dominance effects (I will also refer to as *auditory overshadowing and visual overshadowing, respectively*) have been found under a variety of stimuli (Napolitano & Sloutsky, 2003) and task conditions (Robinson & Sloutsky, 2004).

While the findings of modality dominance have provided new information about how children process cross-modal input, several questions about modality dominance remain, and moreover the broader implications of modality dominance for cognitive development have yet to be established.

First, although the previous research has demonstrated that young children can exhibit either auditory or visual overshadowing, the factors that determine the type of overshadowing have not been fully fleshed out. Specifically, it is unclear what happens to modality dominance when the relative familiarity of auditory and visual stimuli is manipulated. It is also unclear whether modality dominance effects can be found with label-like auditory input. It is possible that familiarity of auditory stimuli contributes to processing in the same manner as familiarity of visual stimuli, such that when auditory stimuli are more familiar than visual stimuli, auditory stimuli overshadow visual stimuli. Furthermore, it is possible that linguistic stimuli also contribute above and beyond general auditory effects.

Second, although the research has suggested that modality dominance can shift flexibly in young children, the mechanism that is responsible for this flexibility is unknown. One possibility is that in the course of cross-modal processing, the two modalities race for attention (cf. Logan's ITAM model, 2002), and whichever modality wins the race takes over processing, thus effectively overshadowing (or attenuating processing of) the other modality. Because the attentional system functions to optimize processing (cf. Logan, 2002), attention should be first allocated to dynamic, transient input, and since auditory input (including labels) is typically less stable than the visual input it accompanies, instances where time to process cross-modal information is limited produce auditory overshadowing effects (e.g., Robinson & Sloutsky, 2004; Sloutsky & Napolitano, 2003). Furthermore, because familiar stimuli are more likely to engage attention than novel stimuli (e.g., Christie & Klein, 1995), familiar visual input overshadows less familiar auditory input, and thus result in visual dominance effects (e.g., Napolitano & Sloutsky, 2003). If attentional constraints are responsible, several testable predictions could be made. For example, because auditory dominance appears to be the default, and visual dominance is the result of learning (as it is dependant on the familiarity of visual input), it is reasonable to expect that auditory dominance is a more basic and robust phenomenon than visual dominance, and as such it should be harder to ignore dominant auditory input.

Third, it is unclear what the broader implications of modality dominance are. For example, it has been suggested that conceptual development may be affected by modality dominance, such that overshadowing effects may help to explain the effects of labels on a variety of cognitive tasks requiring cross-modal processing, including similarity

judgment, categorization, and induction. To this end, Sloutsky & Napolitano (2003) have argued for a general-auditory hypothesis for label effects on cognitive tasks. This hypothesis, although not mutually exclusive to linguistic hypotheses (see Gelman & Markman, 1986; Baldwin & Markman, 1989; Waxman & Markow, 1995; Balaban & Waxman, 1997), does provide a more basic account for why children use labels on cognitive tasks by suggesting that effects of labels might not be limited to language-specific factors, but that these effects may also stem from a privileged processing of auditory information (and possibly other types of input that automatically engage attention) by young children. If this is the case, the effects of labels on conceptual tasks should be explained by the low level attentional factors that produce auditory overshadowing.

Overall, although research examining modality dominance shows promise in providing some insight into how attention may affect the ability to process input at different points of development, more information is needed as to what happens when auditory input is more familiar or more language like, the extent to which young children's shifts between auditory and visual dominance are automatic or deliberate, and whether overshadowing affects children's performance on conceptual tasks, such as induction and categorization.

In the review that follows, I unpack modality dominance effects and examine them in greater detail, discuss the role of attention in modality dominance, present research on label use in conceptual development, and generate testable hypotheses to address some of the questions concerning modality dominance. After the review, I present three separate phases of research each designed to address a separate set of hypotheses.

CHAPTER 1

MODALITY DOMINANCE EFFECTS

As stated in the introduction, mapping new linguistic labels to new objects typically requires the cross-modal processing of arbitrarily presented auditory and visual input. While processing of both types of input is required to learn a new label, research on cross-modal processing has repeatedly demonstrated that under these conditions, the two modalities often compete for attention, which may result in cross-modal interference effects. Thus, input that participants ably process in a unimodal condition, can be overshadowed by input from another modality under bimodal presentation conditions. Furthermore, this research has resulted in the discovery of different modality dominance effects at different stages of development: infants exhibit mostly auditory overshadowing (Lewkowicz, 1988a; Lewkowicz, 1988b; Robinson & Sloutsky, 2004), adults exhibit mostly visual overshadowing (Colavita, 1974; Colavita & Weisberg, 1979), while young children exhibit evidence of both auditory and visual overshadowing (Sloutsky & Napolitano, 2003; Napolitano & Sloutsky, 2003; Robinson & Sloutsky, 2004).

Modality Dominance Effects in Infants. Auditory overshadowing in infants was established in a set of experiments in which the processing of temporally based auditory-visual compounds by six-month-old infants was examined to determine the relationship

between the auditory and visual modalities when information from both modalities competes for the infant's attention (Lewkowicz, 1988a). Infants were habituated to compounds of auditory (i.e., single tones) and visual (i.e., checkerboard images) stimuli. Once habituated, subjects were then presented with one of three types of test trials that differed from the habituated stimuli by one of the following: temporal aspects of visual stimulus, temporal aspects of the auditory stimulus, or temporal aspects of both auditory and visual stimulus. Infants did not dishabituate to temporal differences in the visual stimuli, but did for the auditory stimuli. Furthermore, this finding held even when the intensity for the visual stimuli was twice that of the auditory stimuli. The results demonstrated that when temporally modulated visual stimuli are in competition with auditory stimuli, the auditory stimuli overshadow the visual stimuli. Next, the same experiments were conducted with ten-month-old infants (Lewkowicz, 1988b), who unlike the 6 month-olds, did discriminate temporal changes under some of the conditions; however, they still were more consistent in discriminating auditory temporal changes. These findings suggest that although between the ages of 6 and 10 months there is a shift towards a greater capacity to respond to complex, multisensory information, the auditory modality still receives privileged processing.

More recently, in a variant of the multimodal component variation task used by Lewkowicz (1998a, 1998b), Robinson and Sloutsky (2004) familiarized infants (8-month-olds, 10-month-olds, and 16-month-olds) with a compound auditory-visual stimulus. At test, either the auditory, visual, or both components changed, and looking time responses were measured. If infants attend to only auditory input during familiarization, then looking should increase when auditory input changes. If infants

attend to only visual input during familiarization, then looking should increase when visual input changes. Finally, if infants attend to both auditory and visual input during familiarization, then looking should increase when either input changes. For infants in all age groups looking only increased when the auditory component changed, and thus the infants exhibited auditory overshadowing when auditory and visual stimuli were presented in compounds, even though they had no difficulty discriminating the same visual stimuli when they were presented in isolation.

Modality Dominance Effects in Adults. Visual overshadowing in adults was established in a series of studies demonstrating that when presented with auditory-visual compounds, they more readily detect visual stimuli than auditory stimuli (Colavita, 1974; Colavita & Weisberg, 1979; Egeth & Sager, 1977). In particular, when presented with auditory-visual compound stimuli and asked to press one key when detecting an auditory stimulus and another key when detecting a visual stimulus, participants were more likely to press the “visual” key than the “sound” key, or they pressed the former before the latter. Furthermore, under some conditions, participants failed to notice the sound component in the bimodal condition, whereas the same sound was readily detected in the unimodal condition (Colavita, 1974).

Modality Dominance Effects in Young Children. In a set of experiments, Sloutsky & Napolitano (2003) examined auditory preference (a tendency to treat the auditory component of an auditory-visual compound stimulus as a more important cue than the visual component) in young children. To determine whether young children have a preference for auditory stimuli, 4-year-olds were tested using a modified version of the “switch” task (see Werker, Cohen, Lloyd, Casasola, & Stager, 1998, for a description of

the original task). Visual stimuli (see Figure 1 for an example of such stimuli) were either unfamiliar landscapes (Experiment 1) or three shape patterns (Experiment 3), and the auditory stimuli were computer generated three tone patterns. In this task, 4-year-olds (and adults) were trained to select a particular combination of an auditory-visual stimulus (AUD_1VIS_1) over another combination of an auditory-visual stimulus (AUD_2VIS_2). When training was completed, the trained set was broken into two new sets, such that the trained auditory component was paired with a new visual component (AUD_1VIS_{new}) and the trained visual component was paired with a new auditory component ($AUD_{new}VIS_1$). Participants were asked which of the two new sets was the “trained” one. It was found that 4-year-olds overwhelmingly selected AUD_1VIS_{new} , thereby exhibiting auditory preference (whereas the vast majority of adults selected $AUD_{new}VIS_1$, thereby exhibiting visual preference).

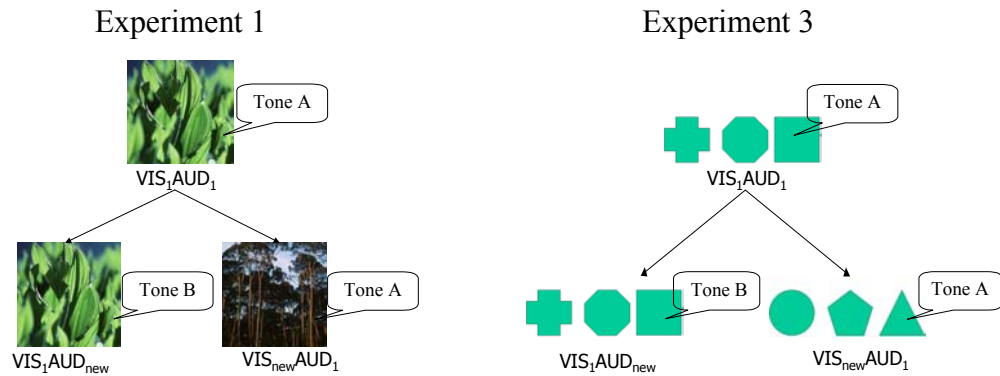


Figure 1. Examples of stimulus sets used in Sloutsky and Napolitano (2003).

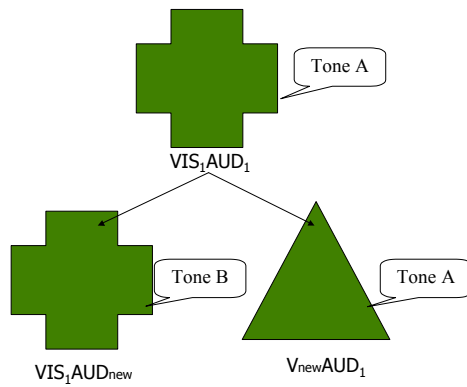
Although 4-year-olds exhibited auditory preference, it remained unclear whether this preference reflected deliberate choice or whether it stemmed from auditory dominance (i.e., the failure to encode visual stimuli). On the one hand, it is possible that young children encoded both the auditory and the visual components and then strategically rejected the latter in favor of the former. On the other hand, it is possible that the auditory modality dominated the visual modality, with the auditory stimuli overshadowing (or preventing processing of) the visual stimuli.

To distinguish between these possibilities, Sloutsky and Napolitano (2003) conducted an immediate Old/New recognition experiment, in which they presented 4-year-olds and adults with a Target stimulus, AUD_1VIS_1 , which was identical to the trained set in the modified switch task. After seeing the Target, participants were presented with one of the following test items: (1) AUD_1VIS_1 , which was the Old Target item, (2) AUD_1VIS_{new} , which had the trained auditory component and a new visual component, (3) $AUD_{new}VIS_1$, which had the trained visual component and a new auditory component, or (4) $AUD_{new}VIS_{new}$, which had a new visual and a new auditory component. The task was to determine whether each presented test item was the same as the Target (i.e., both the same auditory and visual components) or a new item (i.e., differed on one or both components). If participants encode both auditory and visual stimuli, they should correctly respond to all items by accepting Old Target items and rejecting all other test items. Alternatively, if they fail to encode the visual component, they should falsely accept AUD_1VIS_{new} items, while correctly responding to other items. Finally, if they fail to encode the auditory component, they should falsely accept $AUD_{new}VIS_1$ items, while correctly responding to other items.

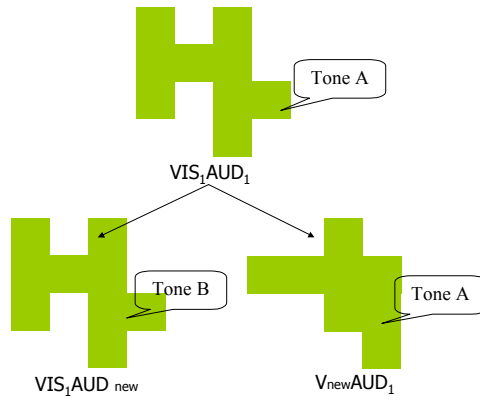
Findings supported the overshadowing possibility, with the auditory modality dominating the visual modality: 4-year-olds failed to encode visual stimuli when these were accompanied by auditory stimuli, erroneously accepting $AUD_1 VIS_{new}$ items. At the same time, these children had no difficulty encoding the visual stimuli in a control condition, when these stimuli were presented without corresponding auditory stimuli, which indicated that the processing of visual stimuli was not difficult per se (note that adults ably encoded both visual and auditory stimuli, although they exhibited marked visual preference in the modified switch task).

However, it was not clear whether this auditory dominance is fixed, such that it exists under all stimuli conditions, or whether it is flexible, such that it exists under some, but not other stimuli conditions. Therefore, to determine the fixedness of auditory dominance, Napolitano and Sloutsky (2003) examined two of the factors that may produce attentional shifts: relative complexity and familiarity of visual and auditory information. Because stimuli used in Sloutsky & Napolitano (2003) were complex and unfamiliar, Napolitano & Sloutsky (2003) used three sets of visual stimuli: (a) simple and familiar (Condition 1); (b) simple and unfamiliar (Condition 2); and (c) complex and familiar (Condition 3). Examples of these stimuli are presented in Figure 2. Again the same modified switch design was used (see Napolitano & Sloutsky, Experiments 1 and 3).

A. Condition 1: Simp+Fam



B. Condition 2: Simp+Nov



C. Condition 3: Comp+Fam

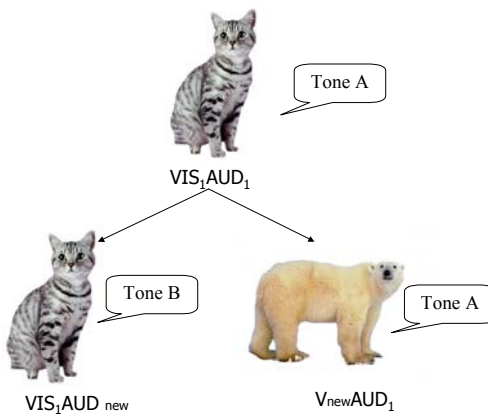


Figure 2. Examples of stimulus sets used in Napolitano and Sloutsky (2003).

Results indicate that when visual stimuli are well familiar (Conditions 1 and 3), 4-year-olds exhibit visual preference, whereas when neither visual nor auditory stimuli are familiar (Condition 2), they are likely exhibit auditory preference.

Again, to determine whether preferences were deliberate choice or produced by overshadowing, participants were tested on the immediate Old/New recognition experiment. Again, findings supported the overshadowing possibility.

Overall, the outcomes of these experiments pointed to several important regularities. First, it was demonstrated that young children exhibit a default auditory dominance: when both auditory and visual stimuli are unfamiliar, young children tend to process auditory stimuli, while failing to process visual stimuli. Thus, when neither sounds nor pictures were familiar, young children exhibited auditory dominance. Second, auditory dominance is a special case of modality dominance: when auditory and visual stimuli are presented simultaneously, young children tend to process stimuli presented in one modality, while failing to process the other modality. In all of the experiments, participants were above chance in encoding only one modality. Third, modality dominance shifts flexibly: under some conditions particular stimuli in Modality 1 overshadow particular stimuli in Modality 2, whereas under other conditions these same stimuli in Modality 1 are overshadowed by different stimuli in Modality 2. For example, the set of sounds that overshadowed visual stimuli in one experiment could be overshadowed by a different set of visual stimuli in another experiment.

Although Sloutsky and Napolitano's findings demonstrating modality overshadowing were robust, the findings did stem from a single paradigm (i.e., immediate recognition task) with particular task conditions (i.e., synchronous presentation of cross-modal

stimuli with a relatively short exposure time), and therefore the scope of generalization was somewhat limited. In order to determine if Sloutsky and Napolitano's findings could be generalized, Robinson & Sloutsky (2004, Experiments 1A and 1B) replicated the modality dominance effects in a variant of an inductive generalization task. In the task 4-year-olds were taught that two separate compounds, AUD_1VIS_1 and AUD_2VIS_2 , each predicted a separate target event. After training, the auditory and visual components were switched so that the auditory component would be predictive of one target event and the visual component would be predictive of different target event (i.e., AUD_1VIS_2 and AUD_2VIS_1). If in the course of learning participants rely on visual information, they should make predictions based on the visual component, whereas if they rely on auditory information, they should make predictions based on the auditory component. In Experiment 1A, two different three-shape-patterns were paired with unfamiliar computer generated sounds, while in Experiment 1B two different single shapes were paired with the unfamiliar computer generated sounds. Overall, results replicated Sloutsky and Napolitano (2003) demonstrating auditory preference when both auditory and visual stimuli were unfamiliar, and visual preference when visual stimuli were more familiar than auditory stimuli. To determine whether the young children encode stimuli in the nonpreferred modality, in Experiment 1C, 4-year-olds were given the same task as either in Experiment 1A or Experiment 1B, except that the preferred modality was removed at test. If participants do encode the nonpreferred modality during training, they should exhibit above-chance accuracy during the test phase, whereas if they do not encode the nonpreferred modality, they should exhibit chance responding. Children were below chance in responding using the nonpreferred modality in both conditions, thereby

demonstrating that they did not encode the nonpreferred modality during training. Thus, this research replicated the pattern of overshadowing effects found by Sloutsky & Napolitano (2003).

What factors contribute to these developmental differences in modality dominance? One possibility entertained by Sloutsky and Napolitano (2003) was that auditory dominance early in development may be attributed to maturational asynchronies between the auditory and visual modality. The auditory system starts functioning during the last trimester of gestation allowing the fetus auditory experience in-utero (Birnholtz & Benaceraff, 1983; see also Jusczyk, 1998, for a review), whereas the visual system does not start functioning until after birth. Therefore, even though by the time the infant is several months old, the visual system functions at the same level of the auditory system (Banks & Salapatek, 1983), because early maturation gives the auditory modality an experiential head-start over the visual modality, it continues to dominate into early childhood. While it seems plausible that this maturational asynchrony could explain auditory overshadowing in infants, both Napolitano and Sloutsky's (2003) and Robinson & Sloutsky's (2004) findings that modality dominance shifts flexibly in young children make this possibility seem less plausible for young children and instead suggest that attentional factors can better account for modality dominance effects in young children. Thus, an attentional account is necessary.

AN ATTENTIONAL ACCOUNT FOR MODALITY DOMINANCE

What is the mechanism underlying modality dominance? The overall theoretical idea is that allocation of attention to a given modality in the course of cross-modal processing is subject to the same choice processes as allocation of attention to objects in visual search tasks and attention to stimulus dimensions in categorization tasks (see Logan, 2002, for a discussion). If this is the case, then choice could be instantiated as a race between the two modalities (cf. Logan's ITAM model). Because, the ability of young children to deliberately allocate their attention is questionable (Kirkham, Cruess, & Diamond, 2003; Robinson & Sloutsky, 2004; Zelazo, Frye, & Rapus, 1996; Smith, Jones, & Landau, 1996), it seems more likely that the choice is determined by the system rather than the choice being a subject of deliberate control.

If the overall attention capacity is fixed (which is not an unreasonable assumption), then whichever modality wins the race takes over processing, thus effectively overshadowing (or attenuating processing of) the other modality. It is also reasonable to assume that the attentional system functions to optimize processing (cf. Logan, 2002). Therefore, because auditory stimuli are transient, whereas visual objects and scenes are usually stable and their presence is protracted, it seems that it is more optimal for the system to process auditory information first. In fact, there is empirical evidence indirectly supporting this assumption: when auditory and visual stimuli of comparable salience are presented simultaneously, auditory input is processed faster than corresponding visual input (e.g., Turatto, Benso, Galfano, & Umiltà, 2002).

Because early in development, attentional resources are more limited than later in development, it is reasonable to expect that (under many conditions) early in development attention should be first allocated to the auditory modality, thus giving rise to auditory overshadowing effects (Napolitano & Sloutsky, 2003; Robinson & Sloutsky, 2004; Sloutsky & Napolitano, 2003). Thus, auditory overshadowing may be an important instance of automatic attention to the type of input that is typically the least stable. At the same time, there is evidence that other types of input also automatically engage attention. Specifically, research has demonstrated that familiar entities are more likely to engage attention than novel stimuli (e.g., Christie & Klein, 1995). Furthermore, there is evidence that the primate brain determines the familiarity of input early in processing, and as such familiar input elicits a different neuronal response than novel input (Holscher, Rolls, Xiang, 2003; Xiang & Brown, 1998). Therefore, if familiar input automatically engages attention, this could take priority over auditory processing, and familiar visual input may overshadow less familiar auditory input, thus resulting in visual dominance effects (e.g., Napolitano & Sloutsky, 2004). However, because auditory dominance is a default and visual dominance (due to its dependence on familiarity of visual input) is a result of learning, it is reasonable to expect that auditory dominance is a more basic and robust phenomenon than visual dominance. In addition, if modality dominance effects stem from automatic pulls on attention, then early in development (when the ability to control attention deliberately is questionable), young children should have difficulty deliberately allocating attention to a non-dominant modality. Finally, if auditory dominance is a more a basic and robust phenomenon than visual dominance, it is

reasonable to expect that it should be more difficult to ignore the dominant modality when the dominant modality is auditory than when the dominant modality is visual.

To summarize, it seems reasonable to speculate that during periods of development when attentional resources are more limited (e.g., early childhood), the attentional system would function best to process the type of input which is typically the most relevant (i.e., highly familiar input) or the least stable (i.e., transient auditory input) before processing less familiar or more stable sources of input, and therefore these familiar or transient types of input are likely to automatically summon attention.

If the processing of cross-modal input is affected by attentional factors (i.e., a default to process transient auditory or familiar input first), then in instances where young children are asked to make conceptual judgments using cross-modal input (e.g., labels paired with the objects they denote), young children's choices could receive a boost by these attentional factors. For this reason, an attentional account of modality dominance may have important implications for understanding of the role of language in conceptual development.

THE ROLE OF MODALITY DOMINANCE EFFECTS IN CONCEPTUAL DEVELOPMENT

Research has repeatedly demonstrated that for young children verbal labels play an important role in conceptual tasks (e.g., Gelman & Markman, 1986; Balaban & Waxman, 1997; Roberts, 1995; Sloutsky & Lo, 1999). For example, if two objects are called “daxes”, young children are more likely to think that they belong to the same category

(Markman & Hutchinson, 1984), and as such they share other properties, even if the objects look quite different (Gelman & Markman, 1986). Thus, under some conditions, labels are capable of outweighing a myriad of physical features. Although the factors that underlie the effects of labels are not fully understood, previous research findings have generated interesting ideas about which specific label property is responsible for salience (Gelman & Markman, 1986; Balaban & Waxman, 1997; Roberts & Jacob, 1991; Sloutsky & Napolitano, 2003). Generally, these explanations fall into one of two categories, arguing that either domain specific or domain general mechanisms are most responsible for label salience.

Domain specific explanations argue that it is one of the linguistic factors of a label (i.e. semantics or phonetics) that give it priority (e.g., Gelman & Markman, 1986; Balaban & Waxman, 1997). Domain general explanations argue that labels gain priority because of basic attentional factors, such as a preference for auditory input (Roberts & Jacob, 1991; Sloutsky & Napolitano, 2003). Of course, these explanations are not mutually exclusive, and it is possible that domain specific and general mechanisms both drive the effects of labels on cognitive tasks as well as facilitate effective acquisition and use of labels. However, in order to establish the role of the different factors, it seems necessary to consider their independent contributions.

Linguistic Explanations for Label Salience. At birth, infants can demonstrate their refined appreciation for speech over other categories of noise (Fernald, 1992; Fernald & Simon, 1984; Cooper & Aslin, 1990). For example, in a study using a rubber nipple with a switch inside that is triggered to play a tape recorder when the infant subject sucks, it was shown that at four days of age French babies suck harder to hear French than Russian

(Mehler, Jusczyk, Lambertz, Halsted, Bertoncini, & Amiel-Tison, 1988), and at one month they sucked harder to hear different syllables rather than the same one repeated (Eimas, Siqueland, Jusczyk, & Vigorito, 1971). Within two months, infants can make categorical discriminations of various phonetic contrasts (Aslin, Pisoni, & Jusczyk, 1983), and categorically discriminate on the basis of context and relational information (Jusczyk, Pisoni, Reed, Fernald, & Myers, 1983). Therefore, because even infants seem capable of identifying and utilizing linguistic input, it seems possible that linguistic input could be privileged in young children's conceptual development.

The semantic hypothesis argues that the effects of linguistic labels stem from two important conceptual assumptions that young children hold: (a) they assume that entities are members of categories, and (b) they assume that labels presented as count nouns convey category membership (Gelman & Coley, 1991). These assumptions lead young children to infer that entities that are denoted by the same count noun belong to the same category (Gelman & Markman, 1986; see also Waxman & Markow, 1995, for a discussion) and therefore support categorization. Furthermore, because linguistic labels denote categories, and because membership in the same category supports induction (e.g., two different species of monkey are more likely to share properties than are a monkey and elephant), linguistic labels support induction.

A variety of studies have demonstrated the important role that labels play in categorization and induction in young children (e.g., Markman & Hutchinson, 1984; Gelman & Markman, 1986; Gelman & Heyman, 1999). Markman and Hutchinson (1984) demonstrated that when objects are not accompanied with labels, children tend to

group objects such as a police car thematically with a policeman. However, when the same police car was presented with a label “dax”, they instead grouped the police car categorically with other vehicles.

Gelman and Markman (1986) demonstrated that young children are more likely to induce properties from one object to another using shared label over perceptual similarity. In a forced-choice task, young children were presented with picture triads: a blackbird that was the target, a flamingo that was perceptually dissimilar from the blackbird, and a bat that was perceptually similar to the blackbird. Both the blackbird and flamingo were referred to as “birds”. The task for the child was to generalize a biological property (e.g., “feeds its young with mashed food” vs. “feeds its young with hard food”) from either the flamingo or bat to the blackbird. The results indicated that young children reliably generalized the biological properties based on the common label “bird” shared between the flamingo and blackbird, rather than on the physical similarity between the bat and blackbird (however, see Sloutsky & Fisher, 2004b for a similarity-based account).

Also, Gelman and Heyman (1999) demonstrated that young children are more likely to generalize properties from one individual to a second individual when they are presented with the noun-like label “a carrot-eater” than when they are simply described as both liking to eat carrots.

The effects of labels on categorization have also been extended to infants. Baldwin and Markman (1989) demonstrated that that spoken labels focus an infant’s attention on an object category. In the experiment 10 to 14 month-old infants were presented with toys that were accompanied by either a spoken label or no sound, and the infants’ looking

times were measured. The findings indicated that infants spend more time examining an object when a label was presented for the object, and thus the spoken labels facilitated attention to objects.

To determine if the reasons labels facilitated attention in infants could be attributed to a specific label-based influence or a more general alerting of language (or sound), Waxman & Markow (1995), habituated 12 month old infants to a series of animal pictures in one of two conditions: a label condition, in which animal pictures were paired with a phrase including a label, such as “See the fauna?”, and a condition that included speech without any labels, such as “Look what’s here”. On the final two trials, the infant was then presented with two new pictures: one from the animal category and one from a novel category (i.e., car). Infants were found to look longer at the novel category picture when a label accompanied it, and it was concluded that the labels facilitate category learning in infancy.

Although the combined results could be taken as evidence that label phrases specifically serve as an invitation to form a category by focusing the infant’s attention on the shared properties of the objects (Waxman & Markow, 1995), it has also been argued that label effects are language specific rather than count noun specific (I will refer to this argument as the phonetic hypothesis).

The phonetic hypothesis argues that facilitative effects of linguistic labels might not be limited to semantic effects, but that additional effects might be due to infants’ and young children’s special attention to the prosodic components of human speech which

distinguish speech from other sounds (Balaban & Waxman, 1997). Thus, children may use labels based on an appreciation for speech sounds in general, rather than the specific sound of a label.

Balaban and Waxman (1997) examined the effects of tone sequences and labels in the categorization of 9-month-olds. The infants were trained on picture slides of a category (e.g., rabbit) with one of the following: a tone, a label (e.g., “rabbit”), or an intelligible content filtered word with the intonational contours of the word preserved. Training was followed by a test phase, which consisted of two pictures: one novel but from the same category (e.g., rabbit) and one using a novel category (e.g., pig). The two pictures were presented simultaneously, as a paired comparison (i.e., stimuli were presented side by side, and the infant must choose to look at one or the other), and looking preferences were recorded. The results demonstrated that both word phrases and content-filtered speech supported categorical responding, whereas the tones did not. Thus, these findings indicate that speech sounds in general facilitate categorizing, since infants should not respond categorically to the content filtered words if they are responding only to semantic properties.

However, while there is a sizable body of evidence that supports the contention that young children will ignore perceptual similarity when conceptual (count nouns) or linguistic information is present when performing categorization and induction, this evidence does not indisputably rule out the possibility that the reasons labels have a privileged status in categorization and induction can be explained by more basic attentional factors. Because semantic and phonetic input is typically presented auditorily

and comes from a highly familiar source (i.e., human voice), it is reasonable to suggest that these results could be confounded with the effects of audition and familiarity.

General-Auditory Explanation for Label Salience. As stated, the linguistic stimuli used in conceptual tasks are not only linguistic, but they are also auditory, and thus a general-auditory hypothesis has been proposed (e.g., Sloutsky & Napolitano, 2003).

The general-auditory hypothesis argues that effects of labels might stem from auditory input (including linguistic labels) partially overshadowing corresponding visual input. Recall that Sloutsky & Napolitano (2003) demonstrated that when visual and auditory stimuli are both unfamiliar, children exhibit auditory dominance. Thus, children's use of labels may stem from differences in processing for auditory and visual stimuli.

The effects of audition alone were also explored by Roberts and Jacob (1991). In a study that examined whether 15-month-old infants would categorize with auditory input void of linguistic properties, infants were habituated to a set of animal line drawings (dogs, cats, and horses) and then presented with either new line drawings from the animal category (deer, pigs, birds) or line drawings from the novel category, car. Visual stimuli were paired with one of two types of auditory stimuli: phrases containing the word "animal" or instrumental music. Detection of a category was measured by comparing looking times between the same category visual stimuli and the novel category visual stimuli. Results indicated that both nonlinguistic input and linguistic input facilitated categorization.

In a study that followed, the same basic design was employed (Roberts, 1995). However, in this study the auditory stimuli (linguistic input or nonlinguistic input) were

presented using one of two procedures: 1) the presentation of auditory stimuli was perfectly correlated with the presentation of visual stimuli, or 2) the auditory stimuli were presented continuously throughout session and did not correlate with visual stimuli presentation. When both types of auditory stimuli were correlated with visual stimuli, categorical responding was facilitated. However, when the presentation of auditory and visual stimuli was not perfectly correlated, the categorical responding was disrupted. Because categorical responding should not have been disrupted when the presentation of auditory and visual stimuli were not perfectly correlated if label salience is dependent upon a label-category link, the results provided further evidence that label salience is not fully explained by linguistic properties.

Sloutsky and Lo (1999) also examined the effects of auditory input in similarity judgment by presenting 6-12-year-olds with line drawings of schematic faces which were paired with either auditorily presented artificial linguistic labels (Experiment 1) or American Sign Language labels that still maintained a semantic component, but had no auditory component (Experiment 3). The children were asked to select the test drawing most similar to the target. In the experiments, one test stimulus always had the same label (spoken or signed) as the target, and the other test stimulus had a unique label (spoken or signed). Researchers varied the number of common and distinct visual features between each of the test stimulus and the target, but the test stimulus with the unique label (spoken or signed) was always more visually similar. The proportion of signed label-based choices was significantly less than the proportion of spoken label-based choices. Thus, the results support the possibility that a label's effect is due to its auditory component rather than its semantic component.

However, Napolitano and Sloutsky (2003) have also provided evidence that familiar visual stimuli can override auditory effects to instead produce visual overshadowing, and therefore, a revised general-auditory hypothesis that considers the full picture of the role of attention in modality dominance should be considered. As a reminder, the attentional account of modality dominance suggests that the information that engages the attentional system first will “win the race” and be processed first, and there is evidence that familiar entities are more likely to engage attention than novel stimuli (e.g., Christie & Klein, 1995). Therefore, when visual input is more familiar than auditory input, visual input will engage attention first, but when auditory and visual information are both unfamiliar, auditory input will be the default in engaging attention first.

This attentional leg up in processing for auditory and familiar input could be enough to give information that is auditory or familiar a boost on conceptual tasks, such that because they are processed first, they are guaranteed a portion of the overall attention given to the task. Thus, even though the attentional demands in the typical conceptual task are typically less than what they are in a task to measure modality dominance (i.e., the immediate recognition task) in that the time to process visual input is significantly longer (the visual input is typically presented throughout a given trial), because the auditory and familiar stimuli grab attention first, they gain a slight edge over information that is subsequently processed.

If modality dominance effects do in fact give auditorily presented linguistic labels a boost on conceptual tasks, then this boost may be accountable for at least a portion of

label effects. Furthermore, if it is the case that basic attentional factors may be enough to explain label based categorization and induction, then a conceptual explanation may be altogether unnecessary.

ISSUES AND HYPOTHESES

Although Sloutsky and Napolitano (2003) and Napolitano and Sloutsky (2003) have introduced a novel and robust account to how young children process arbitrarily paired visual-auditory input, more research is needed to fully understand auditory and visual overshadowing in young children. Furthermore, although the researchers (e.g., Sloutsky & Napolitano, 2003; Robinson & Sloutsky, 2004) have speculated that modality dominance could underlie some of the effects of labels in young children's conceptual performance, previous research has not directly examined whether modality dominance effects can explain these label effects. Therefore, the current research was conducted to address the following questions: 1) Are there familiarity effects for auditory stimuli as well and does the addition of prosodic or semantic components contribute above and beyond general auditory and familiarity effects?, 2) To what extent are young children capable of switching between modalities and can this switching be deliberately controlled?, and 3) Do modality dominance effects affect what input children process in a categorization task?

The first set of unresolved questions speaks to the potential roles of familiarity and linguistic features in mediating modality dominance. Napolitano and Sloutsky (2003) demonstrated that visual stimuli are capable of overshadowing auditory stimuli when

they are more familiar than the auditory stimuli. Since I have argued that auditory dominance is the default and that more familiar stimuli are likely to engage attention faster than novel stimuli, it seems reasonable to predict that as long as visual stimuli are not more familiar than auditory stimuli, then auditory input should overshadow visual input. Further, if this account is correct, the effects found for linguistic input should be explained by general auditory and familiarity effects, with little or no additional contribution from linguistic factors. In Chapter 2, I test these predictions and further flesh out what mediates modality dominance by examining these effects when the relative familiarity of auditory and visual stimuli is manipulated and auditory input becomes more label-like.

The second set of unresolved questions speaks to the role of attention in modality dominance effects. I have argued that if modality dominance effects stem from automatic pulls on attention, then early in development (when the ability to control attention deliberately is questionable), young children should have difficulty deliberately allocating attention to a rejected modality. Additionally, if auditory dominance is a more basic and robust phenomenon than visual dominance, it is reasonable to expect that it should be more difficult to ignore the dominant modality when it is auditory than when the dominant modality is visual. In Chapter 3 I examine the extent to which modality dominance is automatic by mixing trials that have been demonstrated to produce auditory and visual dominance to establish how attention shifts between the two types of trials, and examine the extent to which modality dominance is deliberately controlled by giving explicit instructions to ignore a dominant modality.

The third set of unresolved questions speaks to the role the role of modality dominance in conceptual development. I have argued that the effects of labels might not be limited to language-specific factors, but that these effects may also stem from input that receives privileged processing (auditory input mediated by the familiarity of input) partially overshadowing the corresponding input that is not privileged. If this is true, in a task that examines how children use different types of input to categorize, linguistic input effects should not differ from the effects of other types of auditory input that are capable of overshadowing visual input. In Chapter 4 I use a categorization task to test whether different types of auditory input that do not resemble count nouns (or even language) produce effects similar to that of count nouns on the same task.

Overall, the goal of these three separate phases of research is to provide some answers for these unresolved questions, thereby giving us a much more complete picture of modality dominance and its possible contribution (if any) to conceptual development.

CHAPTER 2

THE EFFECTS OF MANIPULATIONS OF AUDITORY INPUT ON MODALITY DOMINANCE IN YOUNG CHILDREN

The overall goal of this first phase of research is to further flesh out the factors that contribute to modality dominance. To this end, the experiments of Chapter 2 are an extension of Sloutsky and Napolitano's previous findings.

Recall that findings of Sloutsky and Napolitano (2003) and Napolitano and Sloutsky (2003) established two important regularities. First, when both visual and auditory stimuli were unfamiliar, young children exhibited auditory preference, and failed to encode visual stimuli. Second, when only visual stimuli were familiar, young children exhibited visual preference and failed to encode auditory stimuli. Therefore, the familiarity of visual stimuli clearly contributes to the likelihood that young children will attend to visual stimuli. However, while the visual stimuli varied between experiments, the auditory stimuli were always the same unfamiliar 3-tone-patterns, and since all previous experiments used unfamiliar auditory stimuli, it remains unknown whether familiarity of auditory stimuli also may contribute to the processing of auditory information.

It may be the case that with unfamiliar auditory stimuli auditory processing is at ceiling, and thus, the familiarity of auditory stimuli has little or no effect on processing. It is also possible that familiarity of auditory stimuli contributes to processing in the same manner as familiarity of visual stimuli, such that when auditory stimuli are more familiar than visual stimuli, auditory stimuli overshadow visual stimuli. Thus, this phase of research examines whether auditory stimuli that are highly familiar can overshadow highly familiar visual stimuli.

Also recall that Sloutsky and Napolitano (2003) proposed that for young children, the effects of labels in conceptual tasks may be explained by auditory factors. However, their experiments never used auditory input that includes linguistic features, and it is unclear whether linguistic features would further contribute above and beyond general auditory features. It is possible that linguistic features contribute to the salience of auditory stimuli above and beyond the more general, low level auditory (and possibly familiarity) property. It is also possible that linguistic features add nothing to the salience of auditory stimuli, and as such all found effects can be explained by audition (and familiarity) alone. A different possibility is that speech sounds, especially those that resemble English count nouns actually facilitate visual processing (e.g., Waxman & Markow, 1995). If speech produces facilitative effects, then the processing of both visual and auditory input should exceed chance, and overshadowing effects should disappear. Thus, this phase of research examines whether auditory stimuli that are linguistic have any further additive affect.

The four reported experiments use the immediate recognition paradigm from previous experimentation (Sloutsky & Napolitano, 2003; Napolitano & Sloutsky, 2003) to determine the degree of simultaneous encoding of visual and auditory stimuli. In the experiments, auditory stimuli were familiar sounds, vowel patterns, or nonsense count nouns.

The following outcomes are predicted: 1) since familiarity mediates modality dominance, relative familiarity should determine what type of input is encoded, such that more familiar stimuli presented in either modality overshadow less familiar stimuli in either modality, and 2) since linguistic input comes from a highly familiar source, it should overshadow visual stimuli, as long as the familiarity of visual stimuli is less than the linguistic input, but since these effects can be explained by auditory and familiarity effects, linguistic sound effects should not differ from other familiar sound effects.

EXPERIMENT 1

In Experiment 1 familiar common sounds were paired with either less familiar or more familiar visual stimuli in order to examine if there are relative familiarity effects for auditory stimuli.

Method

Participants

Participants were 30 young children (M age= 4.24 years, SD = 0.27 years; 13 girls and 17 boys). In this and all other experiments reported, participants were recruited from childcare centers located in middle-class suburbs of the Columbus, Ohio area, and the majority of the participants were Caucasian. There were 2 between-participants conditions (described below), with 15 children participating in each condition. An additional 2 children did not exhibit above-chance accuracy on control items, and these children were not included in any analyses.

Materials, Design and Procedure

There were two different conditions tested: Sounds More Familiar and Pictures More Familiar. For both conditions, materials consisted of visual/auditory stimulus sets. Within each set, visual and auditory components were presented simultaneously, such that each image's presentation matched the duration of the corresponding sound. The sets were created by randomly pairing an auditory and a visual component.

The Sounds More Familiar Condition. The Sounds More Familiar Condition included auditory stimuli with a higher familiarity rating than that of visual stimuli. Auditory stimuli were 12 different common sounds, such as a doorbell, dog bark, and dial tone. Each sound was one second in duration. Discriminability of these sounds was established in a calibration experiment using a same-different immediate recognition

task. A different sample of 15 4-year-olds made correct same-different judgments after being presented with pairs of the auditory stimuli on 97% of trials. Familiarity of these sounds was established by asking a different sample of 15 4-year-olds two questions about each of the 12 individual auditory stimuli: 1) “Have you ever heard this sound?”, and 2) “What is it?” Overall, the items were reported to be heard before ($M = 94\%$), and were labeled correctly and consistently on 90% of trials. Visual stimuli were 12 different common single shapes, such as a circle or triangle. Each computer-generated two-dimensional shape was 10 cm x 10 cm in size and was colored green. In previous research (Napolitano & Sloutsky, 2003), these stimuli were found to be correctly discriminated by young children on 96% of trials and consistently labeled by young children on 81% of trials. Thus, sounds ($M = 90\%$) were more familiar than shapes ($M = 81\%$).

The Pictures More Familiar Condition. The Pictures More Familiar Condition included visual stimuli with a higher familiarity rating than that of auditory stimuli. Auditory stimuli were the exact same common sounds used in the Sounds More Familiar Condition. Visual stimuli were 12 different 10 cm x 10 cm photographs of highly familiar animals such as cats, dogs, and birds. In previous research (Napolitano & Sloutsky, 2003), these stimuli were found to be correctly discriminated by young children on 100% of trials and consistently labeled by young children on 96% of trials. Thus, visual stimuli ($M = 96\%$) were more familiar than auditory stimuli ($M = 90\%$).

For both conditions, six Target sets (VIS_TAUD_T) were used, and for each Target set, four types of Test items were created: 1) a set that was identical to a Target set (i.e., VIS_TAUD_T), 2) a set that had a different auditory and visual component than a Target set

(i.e., $VIS_{new}AUD_{new}$), 3) a set that matched a Target set's visual component, but had a novel auditory component (i.e., VIS_TAUD_{new}), and 4) a set that had a novel visual component, but matched a target set's auditory component (i.e., $VIS_{new}AUD_T$). Examples of Target and test items are presented in Figure 3.

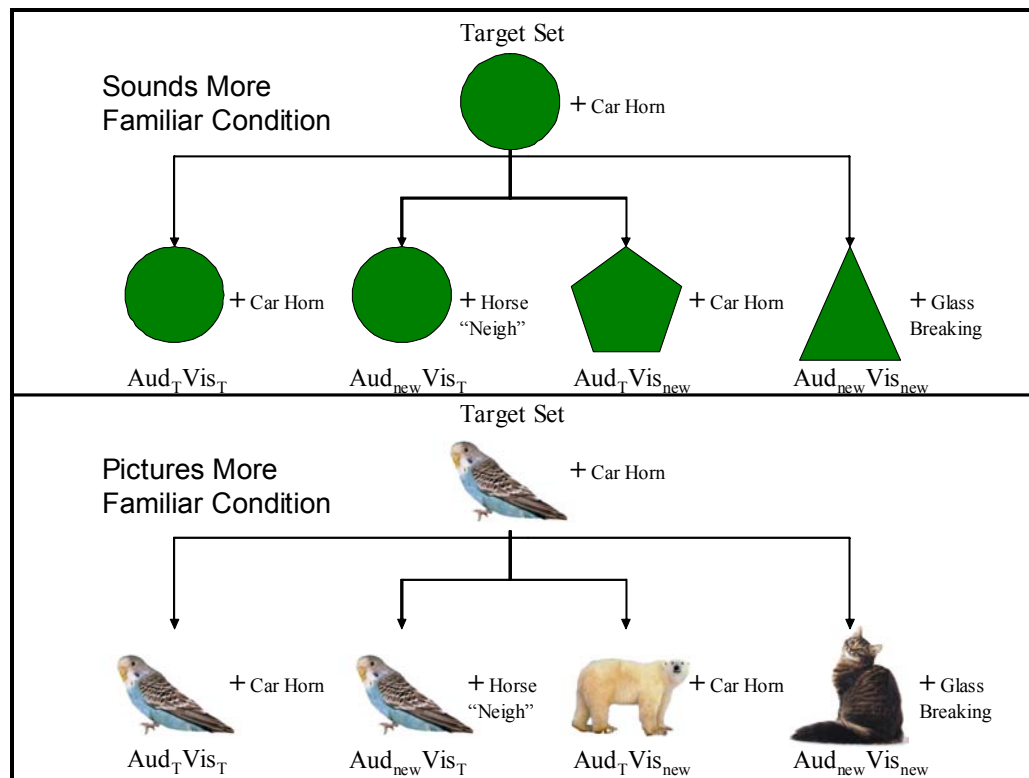


Figure 3: Examples of stimulus sets for Experiment 1.

Design and Procedure

The experiment had a mixed design with the two stimulus conditions varying between participants, and the four test item types varying within participants. A female

experimenter tested participants individually in a quiet room within their daycare centers. Participants were told that they would play a matching game, in which they would be shown a picture and a sound [an example was given at this point], and then another picture and sound [an example was given at this point]. They would need to decide if the second one had the same picture and sound as the first one. If it did, they should answer *SAME*, whereas if it had a different sound, a different picture, or both, they should answer *DIFFERENT*. The experiment included a total of 24 trials (6 Target sets, with 4 Test item types per set). On each trial, a Target set was presented and then followed by Test item, and the participant was then prompted to respond whether the Test item was same as the Target or different. Stimuli were displayed in the following manner. The Target set, VIS_TAUD_T, was presented on the center of the screen for 1 second followed by a blank screen presented for 1 second. Next, one of the four Test items was presented on the center of the screen for 1 second followed by a blank screen, and the participant was asked whether the item was exactly the same as the Target or a different one. After receiving the participant's response, the experimenter entered this response, and started the next trial. Stimuli were presented on a laptop computer running Superlab Pro 2.0 software (Cedrus Corporation, 1999). The presentation order of the six Targets and corresponding Test items was randomized. Participants were given small toys at the end of the experiment as rewards for their participation.

Results and Discussion

Data were analyzed to determine whether children were capable of identifying differences in both auditory and visual stimuli. The VIS_TAUD_T and $VIS_{new}AUD_{new}$ items served as controls for the overall accuracy, whereas accuracy on the VIS_TAUD_{new} and $VIS_{new}AUD_T$ items was indicative of whether participants encoded (a) both components (in which cases they should accurately reject both items), (b) only the visual component (in which cases they should accurately reject $VIS_{new}AUD_T$, but not VIS_TAUD_{new} items), or (c) only the auditory component (in which cases they should accurately reject VIS_TAUD_{new} , but not $VIS_{new}AUD_T$ items).

Across conditions, participants were accurate in accepting VIS_TAUD_T items ($M_{correct} > .92$), and in rejecting $VIS_{new}AUD_{new}$ items ($M_{correct} > .89$), both above chance, one-sample t s (14) > 9.2 , $ps < .01$, with no significant differences in accuracy across the control item types. At the same time, participants exhibited marked differences in processing auditory and visual stimuli across the conditions (see Figure 4).

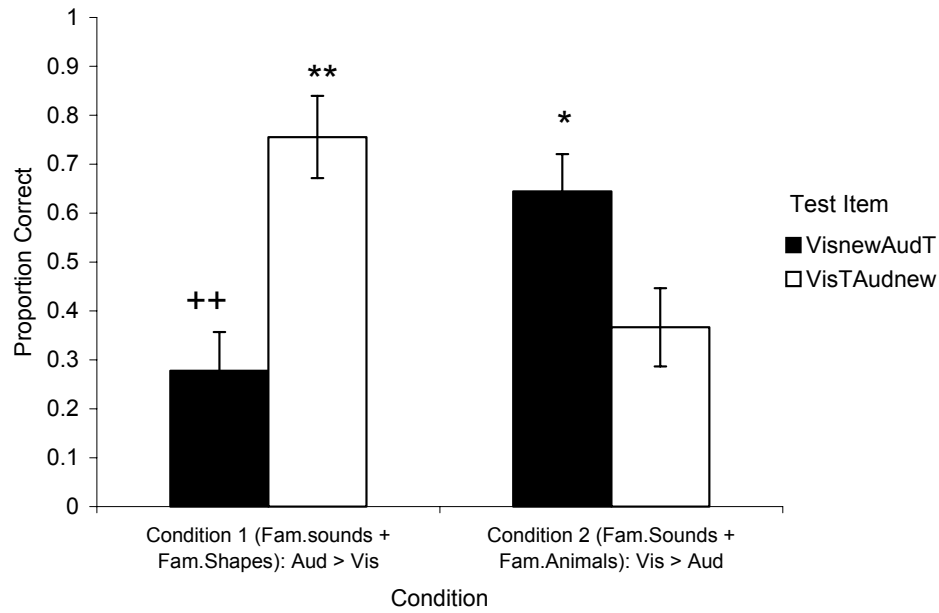


Figure 4. Proportions of correct same/different responses in Experiment 1. Error bars represent standard errors of the mean. Note: ** -- above chance, $p < .02$; ++ -- below chance, $p < .02$; * -- marginally above chance, $p < .07$.

Proportions of selections for auditory stimuli were subjected to a mixed 2 (Condition) by 2 (Test Item Type: VIS_TAUD_{new} and VIS_{new}AUD_T) ANOVA with the test item type as a repeated measure. While none of the main effects were significant, there was a significant Test Item Type by Condition interaction, $F(1, 28) = 22.12, p < .01$. Paired sample t-tests pointed to the following difference: In Condition 1 (i.e., when auditory stimuli were more familiar than visual stimuli) participants were more likely to accurately reject VIS_TAUD_{new}, $t(14) = -4.16, p < .01$, while in Condition 2 (i.e., when visual stimuli were more familiar than auditory stimuli) participants were more likely to reject VIS_{new}AUD_T, $t(14) = 2.47, p = .026$.

These results strongly indicate that the relative familiarity of stimuli may moderate modality dominance – more familiar stimuli overshadow processing of less familiar stimuli. The results are remarkable because the same auditory stimuli that overshadowed visual stimuli in Condition 1 (Aud > Vis), where they were more familiar than the corresponding visual stimuli, were overshadowed by visual stimuli in Condition 2 (Vis > Aud), where they were less familiar than the corresponding visual stimuli.

However, it is reasonable to suggest that there is more difference between shapes and animals than just relative familiarity, and that the results of Experiment 1 could also be explained by some of the stimulus types appearing more interesting than others. Thus, it is possible that pictures of animals overshadowed the sounds because the animals were more “interesting” to young children than the sounds, which was not the case for simple shapes. This concern could be addressed by pairing animal photographs of animals that are unfamiliar to young children with the familiar sounds to determine if familiar sounds are capable of overshadowing animal pictures.

EXPERIMENT 2

In order to address the concern that children made animal picture selections because animals are more exciting, rather than because the animal pictures were more familiar, Experiment 2 paired the same Familiar Common Sounds used in Experiment 1 with photographs of animals that are unfamiliar to young children.

Method

Participants

Participants were 13 young children (M age= 4.34 years, SD = 0.37 years; 8 girls and 5 boys). An additional 2 children also participated, but they did not exhibit above-chance accuracy on control items, and these children were not included in any analyses.

Materials, Design and Procedure

Auditory stimuli were the same common sounds used in Experiment 1. Visual stimuli were close-up portrait photographs of unusual animals, such as a porcupine and a cuscus (see Figure 5 for an example of these stimuli). Again, to establish the degree of familiarity of the visual stimuli, a separate calibration study was conducted using a different sample of 15 4-year-olds. Similar to previous experiments, familiarity was established by asking two questions about each individual visual stimulus: 1) “Have you ever seen this animal before?”, and 2) “What is it?” Overall, children reported that they recognized the stimuli on a little more than half of the trials ($M = 58\%$), whereas they rarely correctly and consistently labeled these animals ($M = 10\%$), although they attempted to label the stimuli on approximately half of the trials ($M = 47\%$). Based on these responses, it was concluded that the visual stimuli were less familiar than the auditory stimuli. The experiment had the exact same design and procedure as Experiment 1.

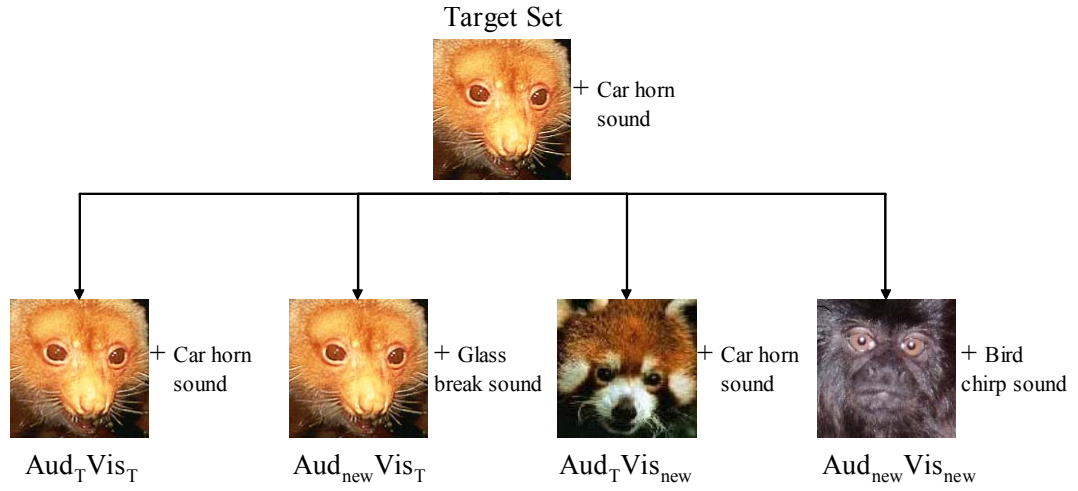


Figure 5. Example of stimulus sets for Experiment 2.

Results and Discussion

Overall, children exhibited high levels of accuracy, correctly rejecting VIS_{new}AUD_{new} items ($M_{\text{correct}} > .90$) and correctly accepting VIS_TAUD_T items ($M_{\text{correct}} > .93$), both above chance, one-sample t s (12) > 8.90, p s < .01, with no significant differences in accuracy across the control item types. More importantly, children readily noticed changes in the auditory component, correctly rejecting VIS_TAUD_{new} items, with accuracy above chance, one-sample t (12) = 3.48, p < .01, but did not notice changes in the visual component, erroneously accepting VIS_{new}AUD_T items, with accuracy at chance, one-sample t (12) = -1.2, p > .25. In short, participants accurately encoded the auditory stimuli, while failing

to reliably encode the visual stimuli, thus indicating that more familiar auditory stimuli overshadowed less familiar visual stimuli. Therefore, the results of Experiment 1, where visual stimuli overshadowed auditory stimuli, are more likely to stem from greater familiarity of the visual stimuli than from them being the more interesting stimuli.

Overall, results of Experiments 1-2 reveal flexible modality dominance and factors underlying shifts in modality dominance. These findings extend those of Sloutsky and Napolitano (2003), and as mentioned in Chapter 1, may have important implications children's performance on conceptual tasks. However, auditory stimuli used have always been non-linguistic sounds, and it is unclear whether findings with these stimuli would generalize to linguistic stimuli. For example, it could be argued that if familiarity does drive modality dominance, then the task of word learning should be impossible because new words are unfamiliar and, as such, could not be attended to when they accompany even somewhat familiar entities. Therefore, because we know that young children do acquire unfamiliar words, the findings reported in Experiments 1-2 may have little or no implication for children's performance on conceptual tasks. Alternatively, it could be argued that the familiarity of auditory stimuli is determined by the familiarity of its source (see Ballas, 1993; Cycowicz & Friedman, 1998, for related discussions). If this is the case then even unfamiliar words should represent a class of highly familiar sounds, as their source (i.e., human voice) is highly familiar to young children, and findings reported in Experiments 1 and 2 should predict processing of cross-modal compounds in which linguistic stimuli are paired with visual stimuli. Thus, because human voice is a highly familiar source, sounds are produced by human voice (even if strings of sounds

unfamiliar and not word-like) are a familiar class of sounds, and as such these stimuli would produce auditory effects similar to those reported for the sounds in Experiments 1 and 2.

EXPERIMENT 3

In order to examine if sounds that are unfamiliar strings which are not word-like, but are produced by the highly familiar source of human voice, can produce auditory effects similar to those reported for the sounds in Experiments 1 and 2, a set of vowel patterns were paired with the same sets of visual stimuli used in Experiment 1.

Method

Participants

Participants were 30 young children (M age= 4.45 years, SD = 0.26 years; 16 girls and 14 boys). There were 2 between-participants conditions (described below), with 15 children participating in each condition. An additional 6 children also participated in Experiment 3, but they did not exhibit above-chance accuracy on control items, and these children were not included in any analyses.

Materials, Design and Procedure

Auditory stimuli were nonsensical three-vowel sequences that did not resemble English words (e.g. “[ə]-[i]-[u]”). Syllable sequences were created by recording a

human speaker generating three syllables, and then cutting each individual syllable to a uniform length of 0.33 seconds using the audio program CoolEdit 2000 so that each sound is approximately one second in duration. These stimuli were presented at the average sound level of 67.8 dB (with a range from 66 dB to 72 dB), which is comparable with the sound level of human voice in a regular conversation. Discriminability was established in a separate calibration experiment using a same-different immediate recognition task. A different sample of 15 4-year-olds correctly made same-different judgments after being presented with pairs of the auditory stimuli on 94% of trials. Familiarity was established by asking a different sample of 10 4-year-olds to make a source attribution for different types of sounds on a forced choice task. This familiarity task differed somewhat from the task described in Experiments 1 and 2. Two classes of sounds were used: (a) vowel patterns (e.g., “[u]- [u]- [e]”) and (b) the familiar animal sounds (e.g., dog bark) which comprised half of the familiar sounds used in Experiments 3 and 4. In the task, participants were told that they would be playing a game in which they would need to guess who was making the funny noise. Each child participated in 24 trials. For each trial participants were presented a sound with four different pictures of possible sources of the sound (see Figure 6, for an example of choice option), and asked “which of these do you think made this sound?” The pictures varied across trials but always included a picture of a man, a familiar animal, an unfamiliar animal, and a question mark (it was explained to the child before the task began that if they were not sure who produced the sound they should point to the question mark). In half the trials, pointing to the picture of the man was the correct response, and in the other half, pointing to the picture of the familiar animal was the correct response. Overall, children correctly

attributed vowel patterns ($M = 94\%$) as well as familiar animal sounds ($M = 98\%$). The latter measure is compatible with the measure of familiarity of familiar sounds presented in Experiment 3, thus indicating that this procedure was an adequate measure of familiarity.

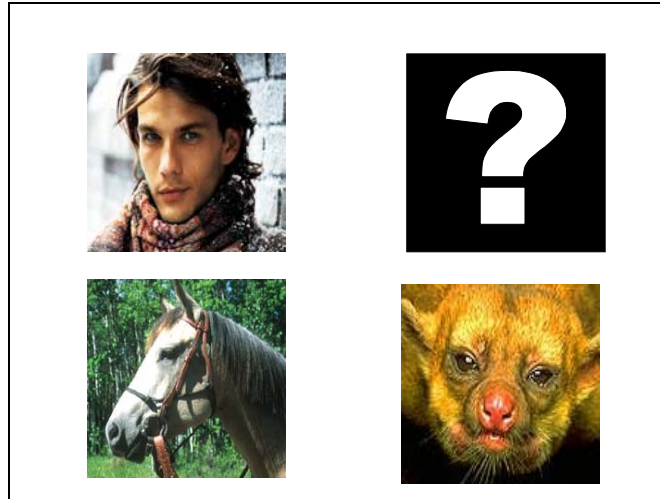


Figure 6. Example of picture choices for a trial in familiarity control task for Experiment 3.

Again, two of the previously tested sets of familiar visual stimuli were used in this experiment. For the Sounds More Familiar Condition, visual stimuli were the common shapes. Common shapes were rated as less familiar ($M = 81\%$) than vowel patterns ($M = 94\%$). For the Pictures More Familiar Condition visual stimuli were the familiar animal photographs. Familiar animals were rated as more familiar ($M = 96\%$) than vowel patterns ($M = 94\%$). The experiment had the same design and procedure as Experiment 1.

Results and Discussion

Again data from the VIS_TAUD_T and VIS_{new}AUD_{new} conditions served as controls, and the data from the VIS_TAUD_{new} and VIS_{new}AUD_T conditions were indicative of whether participants encoded auditory and visual stimuli. Proportions of correct same/different responses are presented in Figure 7. Across conditions, participants were accurate in accepting VIS_TAUD_T items ($M_{\text{correct}} > .93$), and in rejecting VIS_{new}AUD_{new} items ($M_{\text{correct}} > .88$), both above chance, one-sample $t_s(14) > 11.00$, $p_s < .01$, with no significant differences in accuracy across the control item types.

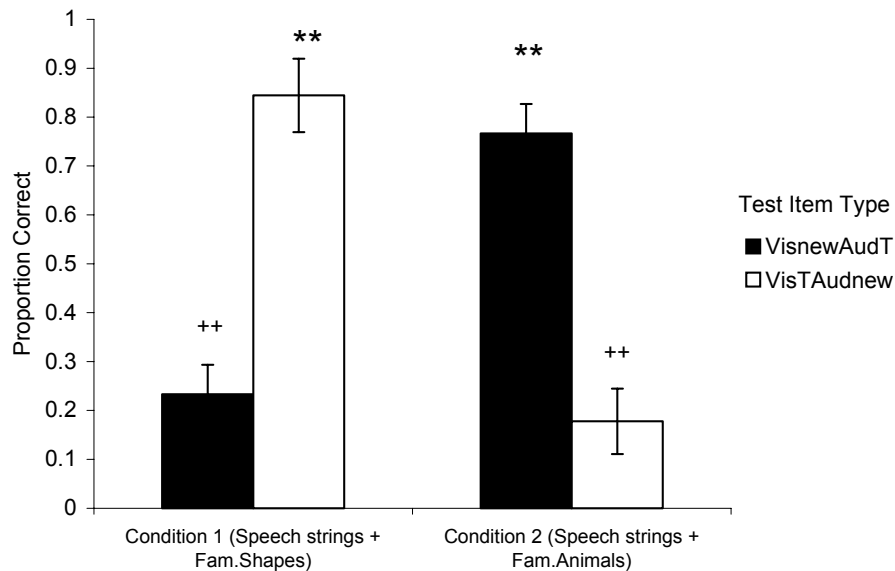


Figure 7. Proportions of correct same/different responses in Experiment 3. Error bars represent standard errors of the mean. Note: ** -- above chance, $p < .01$; ++ -- below chance, $p < .01$.

Proportions of selections for auditory stimuli were subjected to a mixed 2 (Condition) by 2 (Test Item Type: VIS_TAUD_{new} and VIS_{new}AUD_T) ANOVA with the Test Item Type as a repeated measure. While none of the main effects were significant, there was a significant Test Item Type by Condition interaction, $F(1, 28) = 85.24, p < .01$. Paired sample t-tests pointed to the following difference: In Condition 1 (i.e., Speech Strings+Fam.Shapes) participants were more likely to accurately reject VIS_TAUD_{new}, $t(14) = 7.26, p < .01$, while in Condition 2 (i.e., Speech Strings+Fam.Animals) participants were more likely to reject VIS_{new}AUD_T, $t(14) = 6.12, p < .01$.

These results suggest that the pattern of responses was similar to that with familiar sounds (see Experiment 1): when visual stimuli were familiar common shapes, participants exhibited auditory dominance, whereas when visual stimuli were familiar animals, participants exhibited visual dominance. These results suggest that even unfamiliar linguistic stimuli (including unfamiliar words) may have an advantage over somewhat familiar visual stimuli because linguistic stimuli stem from a highly familiar source – human speech.

Although the vowel patterns are linguistic, they do not resemble English count nouns. Recall that the semantic hypothesis argues that the effects of linguistic labels on conceptual tasks stem from young children's assumption that labels presented as count nouns convey category membership and young children are able to distinguish count nouns from other types of linguistic input (Gelman & Coley, 1991). Thus, the semantic hypothesis suggests that the effects should be count noun specific (e.g., Gelman & Markman, 1986; Waxman & Markow, 1995). While, it is unclear whether familiar sounds, like these presented in Experiments 1-3, can produce similar effects to count

nouns on conceptual tasks (this is tested in Chapter 4), it is also unclear whether count nouns produce overshadowing effects similar to familiar input in immediate recognition tasks. It is reasonable to speculate that if count nouns work differently from other types of auditory input in conceptual tasks to produce the strongest label effects, then count nouns may work differently in this task. Alternatively, if count nouns gain priority due to auditory and familiarity effects, rather than their specific count noun features that make them identifiable from other types of auditory input, then the effects of count nouns should not differ from the effects of other familiar auditory inputs.

EXPERIMENT 4

In order to examine if there are any additional affects for sounds that resemble English count nouns in an immediate recognition task, a set of these sounds were used in Experiment 4.

Method

Participants

Participants were 30 young children (M age= 4.28 years, SD = 0.31 years; 13 girls and 17 boys). There were 2 between-participants conditions (described below), with 15 children participating in each condition. An additional 4 children also participated in Experiment 4, but they did not exhibit above-chance accuracy on control items, and these children were not included in any analyses.

Materials, Design, and Procedure

As in Experiments 1-3, stimuli were presented in approximately simultaneous sets (as described below). Again, six Targets and the four different Test items were used. Visual stimuli were the same two sets used in Experiments 1 and 3. Auditory stimuli were a set of nonsense count nouns. Each word consists of two syllables, such as “fika” or “batu”. In order to preserve the natural semantic quality of the sounds, each sound is slightly shorter than one second in duration, but each sound's onset matched the onset of visual input. Syllable sequences were created by recording a human speaker. Phonetic similarity of stimuli was systematically manipulated, so that they would all differ by a controlled number of features, including place, manner, and voicing. All auditory stimuli were created using the audio program CoolEdit 2000. The average sound level of auditory stimuli was 67.8 dB (with a range from 66 dB to 72 dB), which is comparable with the sound level of human voice in a regular conversation.

Diagnostics were run to measure both the discriminability and familiarity of the auditory stimuli. The design and procedure for these tasks are identical to those used in Experiment 3. For discriminability a different sample of 15 4-year-olds made correct same-different judgments on more than 98% of trials. For familiarity a different sample of 10 4-year-olds correctly attributed nonsense count nouns on more than 96% of trials.

Again, the same two conditions were tested and the design and procedure was identical to Experiment 1.

Results and Discussion

Overall, results did not differ from those in Experiments 1 and 3. Across conditions, participants were accurate in accepting VIS_TAUD_T items ($M_{\text{correct}} > .93$), and in rejecting VIS_{new}AUD_{new} items ($M_{\text{correct}} > .92$), both above chance, one-sample $ts(14) > 12.04$, $ps < 0.001$, with no significant differences in accuracy across the control item types. Major analyses revealed a pattern similar to Experiments 1 and 3. A mixed 2 (Condition) by 2 (Test Item Type: VIS_TAUD_{new} and VIS_{new}AUD_T) ANOVA with the test item type as a repeated measure demonstrated that none of the main effects were significant, but that there was a significant Test Item Type by Condition interaction, $F(1, 28) = 61.83$, $p < .01$, with paired sample t-tests pointing to the following difference: In Condition 1 (i.e., Nonsense Count Nouns+Familiar Shapes) participants were more likely to accurately reject VIS_TAUD_{new}, $t(14) = 5.94$, $p < .01$, while in Condition 2 (i.e., Nonsense Count Nouns +Familiar Animals) participants were more likely to reject VIS_{new}AUD_T, $t(14) = 4.49$, $p < .01$.

Thus, there was no increase in auditory processing for speech patterns that resembled English count nouns over speech that did not resemble English count nouns or other familiar sources of auditory input.

SUMMARY

The experiments presented in this first phase of research were conducted in order to further flesh out the factors that contribute to modality dominance effects in young

children. Experiments 1 and 2 indicate that relative familiarity moderates modality dominance: when auditory stimuli were more familiar than visual stimuli, young children exhibited auditory dominance, whereas they exhibited visual dominance when visual stimuli were more familiar than auditory stimuli. These results are remarkable because the very same visual stimuli (single shapes) that received full processing and overshadowed corresponding auditory stimuli (tone patterns) in Napolitano and Sloutsky (2003) received little processing and were overshadowed by corresponding auditory stimuli (e.g., familiar sounds) in the reported experiments in which the sounds were more familiar. Experiments 3 and 4 expanded these findings to human speech: results indicated that human speech elicited auditory dominance effects similar to those elicited by other familiar sounds. Thus, auditory dominance effects may also be amplified by the high familiarity of human speech, since the results of Experiment 3 indicate that even meaningless strings of human speech (e.g., a string of vowels “[ə]-[i]-[u]”) belong to a class of familiar sounds, and thus are more likely to be processed than somewhat less familiar visual stimuli. Furthermore, the results of Experiment 4 suggest that count nouns receive no additional privilege in processing due to their specific structure, as the results of the experiment can be fully explained by familiarity effects.

However, across the Experiments (Experiments 1, 3, and 4) when visual stimuli were the more familiar animals, animal pictures overshadowed familiar sounds and both types of linguistic sounds. Thus, none of the sounds tested were capable of overshadowing this type of visual input. The results of Experiment 2 suggest that this finding does not stem from a simple privilege in processing for animals in general: familiar sounds were capable of overshadowing unfamiliar animals. This outcome is not surprising given the

high familiarity of the this set of visual stimuli and suggests that when word-object pairs are presented for limited time, it may be more difficult for young children to encode new words when they are paired with highly familiar objects than it is to encode new words when they are paired with less familiar or novel objects. If confirmed, this hypothesis may provide an interesting extension of research on Mutual Exclusivity, or the tendency of children to extend novel words to novel objects (e.g., Markman & Wachtel, 1988; Merriman & Schuster, 1991).

Overall, these results in conjunction with Sloutsky and Napolitano's previous research (2003; Napolitano & Sloutsky, 2003) point to several regularities. First, there are modality dominance effects, such that under some conditions the auditory modality dominates the visual modality, whereas under other conditions the reverse is true. Second, there are general auditory and familiarity effects, such that when visual and auditory stimuli are unfamiliar, young children exhibit auditory dominance, otherwise more familiar stimuli dominate processing of less familiar stimuli. And finally, while there is evidence for resource shifting across modalities, there is little evidence for resource sharing: under all conditions one modality received full processing, rather than both modalities receiving some processing. In particular, while a dominant modality exhibited reliable above-chance accuracy, accuracy in the other modality never exceeded chance.

The robustness of modality dominance effects suggests that the observed shifts stem from automatic pulls on attention rather than from deliberate selective attention to a single modality. However, although this flexibility can be inferred from the between subject data, it is unclear how this flexibility would manifest itself within subject.

Furthermore, it is unclear whether manipulations to deliberately control attention to a given modality, could produce shifts in the attention allocated to that given modality. Thus, the role of attention in modality dominance is the focus of the second phase of research presented in Chapter 3.

CHAPTER 3

THE ROLE OF AUTOMATIC AND DELIBERATE ATTENTION IN MODALITY DOMINANCE IN YOUNG CHILDREN

The outcomes of Chapter 2 in conjunction with Sloutsky and Napolitano's (2003; Napolitano & Sloutsky, 2003) findings demonstrate that modality dominance shifts flexibly, such that under some conditions, particular auditory input overshadow particular visual input, whereas under other conditions these same auditory input are overshadowed by different visual input. Although this research establishes the basic phenomena of modality dominance, it leaves several questions unanswered. Specifically, how flexible is modality dominance and what determines the attentional shifts? Also, to what extent can the modality dominance effects be controlled deliberately? Answering these questions is the goal of this phase of research.

Recall from Chapter 1, the proposed theoretical account for the mechanism underlying modality dominance. According to this account, during cross-modal processing the allocation of attention to a given modality is subject to choice processes instantiated as a race between the two modalities (see Logan, 2002, for Logan's ITAM model), where choice is system determined, rather than being under deliberate control. Because the attentional system functions to optimize processing (cf. Logan, 2002),

attention should be first allocated to dynamic, transient input. Thus, instances where time to process cross-modal information is limited (i.e., as in the immediate recognition paradigm) give rise to auditory overshadowing effects (Napolitano & Sloutsky, 2003; Robinson & Sloutsky, 2004; Sloutsky & Napolitano, 2003). Furthermore, because familiar stimuli are more likely to engage attention than novel stimuli (e.g., Christie & Klein, 1995), familiar input overshadows less familiar input (e.g., Experiments 1-4), such that auditory dominance can be reversed when visual input is more familiar than auditory input. However, because visual dominance (due to its dependence on familiarity) is a product of attentional learning (cf. Posner, et al., 1976), auditory dominance operates as the developmental default, and as such auditory dominance is more basic, and therefore may be a more robust phenomenon than visual dominance. In addition, if modality dominance effects stem from automatic pulls on attention, young children, whose ability to deliberately control attention is questionable, should have difficulty deliberately allocating attention to a non-dominant modality over a dominant modality. This should be especially true for the default auditory modality, and as such it should be more difficult to ignore the dominant modality when the dominant modality is auditory than when the dominant modality is visual.

In Sloutsky and Napolitano's previous research, as well as the research presented in Chapter 2, the attentional shifts between auditory and visual dominance were inferred from a between-subject design, and this design does not allow the examination of these shifts within the same participants. For this reason the study of within-subjects shifts is of critical importance because it can provide insight into the relationship between auditory and visual dominance. In particular, it is possible that auditory and visual

dominance do not affect each other, in which case participants would flexibly switch from auditory to visual dominance. It is also possible that participants have difficulty switching from auditory dominance to visual dominance and from visual dominance to auditory dominance. Another possibility is that there is an asymmetry in switching, such that switching from dominance A to dominance B is easier than from dominance B to dominance A. Finally it is possible (although unlikely) that modality dominance effects would disappear, with participants ably encoding stimuli presented to both modalities.

Also unclear is the extent to which attention to the dominant modality can be deliberately controlled. It is possible that both dominant auditory and visual input can be ignored deliberately. It is also possible that participants have difficulty deliberately ignoring both dominant auditory and visual input. Another possibility is that there is an asymmetry in deliberate attention, and it is harder to deliberately ignore input for dominance A than from dominance B.

To examine the role of attention in modality dominance, I examine the extent to which modality dominance is automatic and the extent to which modality dominance is deliberately controlled. The five reported experiments again use the immediate recognition paradigm from previous experimentation (Sloutsky & Napolitano, 2003; Napolitano & Sloutsky, 2003, Chapter 2) to determine the degree of simultaneous encoding of visual and auditory stimuli. In the experiments, either 1) trials or blocks of trials that produce visual and auditory dominance are mixed together to examine how attention shifts between the two types of trials, or 2) explicit instructions are given to ignore the dominant modality to examine the extent to which modality dominance is deliberately controlled.

The following outcomes are predicted: 1) since auditory dominance is more basic and robust than visual dominance, mixing trials or blocks should have more of an impact on visual dominance than auditory dominance, and 2) since modality dominance effects stem from automatic pulls on attention, then early in development (when the ability to control attention deliberately is questionable), young children should have difficulty deliberately allocating attention to a rejected modality.

EXPERIMENT 5

The goal of Experiment 5 is to replicate the modality dominance effects found in Napolitano and Sloutsky (2003, Experiment 2) and Chapter 2, Experiment 1, Sounds More Familiar Condition. Experiment 5 uses a procedure identical to previous research and compares auditory and visual processing when auditory and visual stimuli are presented simultaneously with the respective unimodal conditions. These data will serve as baselines for all experiments presented in this phase of research.

Method

Participants

Participants were 85 young children (M age= 4.42 years, SD = 0.248 years; 40 girls and 45 boys). There were 2 between-participants bi-modal conditions and 3 between-participants unimodal conditions described below, with 17 children participating in each

condition. Seven additional children, who did not exhibit above-chance accuracy on control items, were not included in the reported sample and were not included in any analyses.

Materials

Two different sets of auditory stimuli (Unfamiliar Tone Patterns and Familiar Sounds) and one set of visual stimuli (Familiar Single Shapes) were used. The Unfamiliar Tone Pattern set included 9 computer-generated tone patterns, each consisting of three unique simple tones. Simple tones varied on timbre (sine, triangle, or sawtooth) and frequency (between 1 Hz and 100 Hz). Each simple tone was 0.3 seconds in duration and was separated by .05 seconds of silence, with total pattern duration of 1 second. In this and other experiments reported here, the average sound level of the tone patterns was 67.8 dB (with a range from 66 dB to 72 dB), which is comparable with the sound level of human voice in a regular conversation. The Familiar Sounds set included 9 different common sounds, such as a doorbell, dog bark, and dial tone. Each sound was 1 second in duration. In this and other experiments reported here, the average sound level of the familiar sounds was 69.1 dB (with a range from 67.2 dB to 72.4 dB). The fact that the sounds in the first set were unfamiliar and the sounds in the second set were familiar was established in a separate calibration experiment with 4-year-old children (see Napolitano & Sloutsky, 2003 and Experiment 1, for details of the calibration experiments with 4-year-olds). Overall, the Familiar Sounds had familiarity rating of 90% and the Unfamiliar Tone Patterns had familiarity rating of 16%.

The Single Shape set included 9 computer-generated single two-dimensional figures. Each shape was 10 cm x 10 cm in size and was colored green (see Figure 3 for examples of the shapes). These shapes were familiar to 4-year-olds ($M = 82\%$, see Napolitano & Sloutsky, 2003, for details). In addition, all visual and auditory stimuli used in research reported here had comparable discriminability established in previous research (see Chapter 2; Napolitano & Sloutsky, 2003; Sloutsky & Napolitano, 2003, for details).

Bimodal Conditions. There were two bimodal conditions: one that elicited visual dominance in previous research (hereafter, the Visual Dominance Condition) and another that elicited auditory dominance in previous research (hereafter, the Auditory Dominance Condition). For both conditions stimuli were auditory-visual compounds, with auditory and visual stimuli presented simultaneously, such that presentation of visual stimuli matched the duration of the corresponding sound. In the Visual Dominance Condition, Familiar Shapes were paired with Unfamiliar Tone Patterns (these pairings were found to elicit visual dominance, see Napolitano & Sloutsky, 2003, Experiment 2). In the Auditory Dominance Condition, Familiar Shapes were paired with Familiar Sounds (these pairings were found to elicit auditory dominance, see Chapter 2, Experiment 1).

For both types of bimodal trials (Visual Dominance and Auditory Dominance), three Target items were used, and for each Target, four types of Test items were created: 1) items that were identical to a Target (i.e., $VIS_{Target}AUD_{Target}$), 2) items that had different auditory and visual components than a Target (i.e., $VIS_{New}AUD_{New}$), 3) items that matched a Target's visual component, but had a different auditory component (i.e., $VIS_{Target}AUD_{New}$), and 4) items that had a different visual component, but matched a

Target's auditory component (i.e., $VIS_{New}AUD_{Target}$). An example of a Target and Test items for the Auditory Dominance Condition is presented in Chapter 2, Figure 3, Sounds More Familiar Condition (note that the Visual Dominance Condition used the exact same visual stimuli but had tone patterns instead of familiar sounds).

Unimodal Conditions. There were 3 unimodal conditions: Unfamiliar Tone Patterns Alone, Familiar Sounds Alone, and Familiar Shapes Alone. For all unimodal trials, participants were presented with the same three Targets as in the bimodal conditions, however, in unimodal auditory trials only the auditory component of the Target was presented (i.e., pictures were removed), and in unimodal visual trials only the visual component of the Target was presented (i.e., sounds were removed). Because the Target and Test items were presented in a single modality, the test items included VIS_{Target} and VIS_{New} (for the Familiar Shapes Alone Condition) and AUD_{Target} and AUD_{New} (for the Tone Patterns Alone and Familiar Sounds Alone Conditions).

Design and Procedure

The experiment had a 2 (Condition: Visual Dominance vs. Auditory Dominance) by 4 (Test item: $VIS_{Target}AUD_{Target}$, $VIS_{New}AUD_{New}$, $VIS_{New}AUD_{Target}$, and $VIS_{Target}AUD_{New}$) mixed design, with Test items varying within participants. In addition, there were three unimodal conditions, Unfamiliar Tone Patterns, Familiar Sounds, and Familiar Shapes. Performance on these conditions served as baselines for bimodal conditions.

A female experimenter tested participants individually in a quiet room within their daycare centers. For the bimodal conditions participants were told that they would play a matching game, in which they would be shown a picture and a sound [an example was

given at this point], and then another picture and sound [an example was given at this point]. They would need to decide if the second one had the same picture and sound as the first one. If it did, they should answer SAME, whereas if it had a different sound, a different picture, or different picture and sound, they should answer DIFFERENT. For unimodal conditions, participants were told that they would play a matching game where they would hear one sound (for the auditory conditions) or see one picture (for the visual condition) and then hear a second sound or see a second picture, and decide if they were same or different. If the two were the same, they should answer SAME, whereas if the two were different, they should answer DIFFERENT.

Each condition included a total of 12 trials (3 Target items, with 4 Test items per Target). On each trial, a Target was presented and then followed by a Test item, and the participant was then prompted to respond whether the Test item was same as the Target or different. Stimuli were displayed in the following manner. The Target was presented on the center of the screen for 1 second followed by a blank screen presented for 1 second. Next, one of the four Test items was presented on the center of the screen for 1 second followed by a blank screen, and the participant was asked whether the item was exactly the same as the Target or a different one. For unimodal auditory conditions, the screen was blank for the entire experiment, but sound presentation was identical to that described above.

After receiving the participant's response, the experimenter entered this response, and started the next trial. Stimuli were presented on a laptop computer running Superlab Pro 2.0 software (Cedrus Corporation, 1999). The order of trial types (i.e., the different test

items) was random. Participants were given small toys at the end of the experiment as rewards for their participation.

Results and Discussion

Across all unimodal conditions, participants were highly accurate accepting Target items and rejecting New items, with accuracy in each condition exceeding 92%. Participants were also highly accurate in accepting Target items and rejecting items with both components changed in the bimodal conditions, with accuracy in each condition exceeding 90%.

In the rest of the analyses, auditory and visual processing in the bimodal conditions is compared to their respective unimodal conditions. Auditory processing was defined as correct rejection of $VIS_{Target}AUD_{New}$ items and visual processing was defined as correct rejection of $VIS_{New}AUD_{Target}$ items. Auditory and visual processing in the bimodal condition was compared to the accuracy of rejecting of New items in the respective unimodal condition.

Auditory and visual processing for the Visual Dominance Condition is presented in Figure 8. Although visual processing did not differ significantly from the unimodal baseline (independent-samples $t < 1$, $p = 0.77$), auditory processing did drop significantly compared to the unimodal baseline (independent-samples $t(32) = 3.74$, $p < 0.005$, $d\text{-prime} = 1.12$), thus demonstrating that participants exhibit visual dominance when unfamiliar tone patterns and familiar shapes are presented simultaneously.

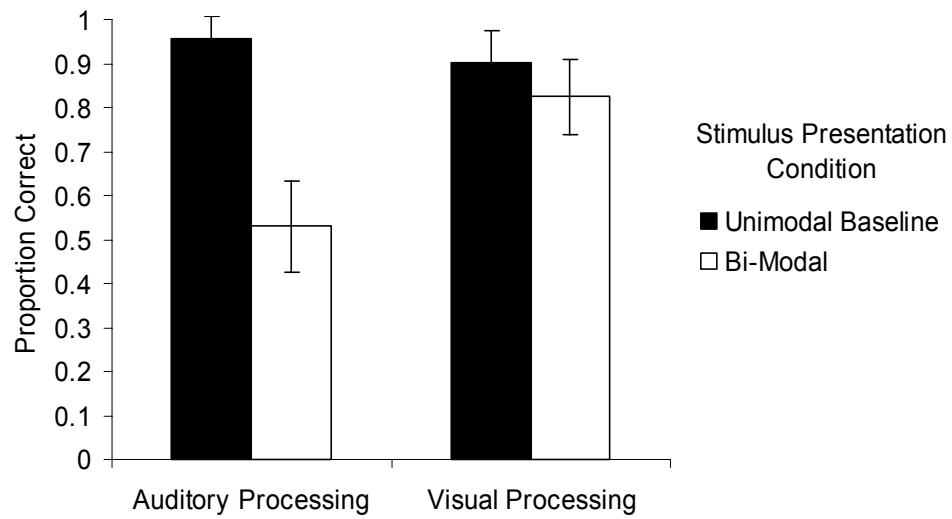


Figure 8. Proportion of Correct Responses in the Visual Dominance Condition in Experiment 5.

Similarly, as shown in Figure 9, in the Auditory Dominance Condition auditory processing did not differ significantly from the unimodal baseline ($p = 0.64$), whereas visual processing did drop significantly compared to the unimodal baseline (independent-samples $t(32) = 4.78, p < 0.001$, $d\text{-prime} = 1.16$). It is also worth noting that auditory and visual dominance effects have comparable effect sizes.

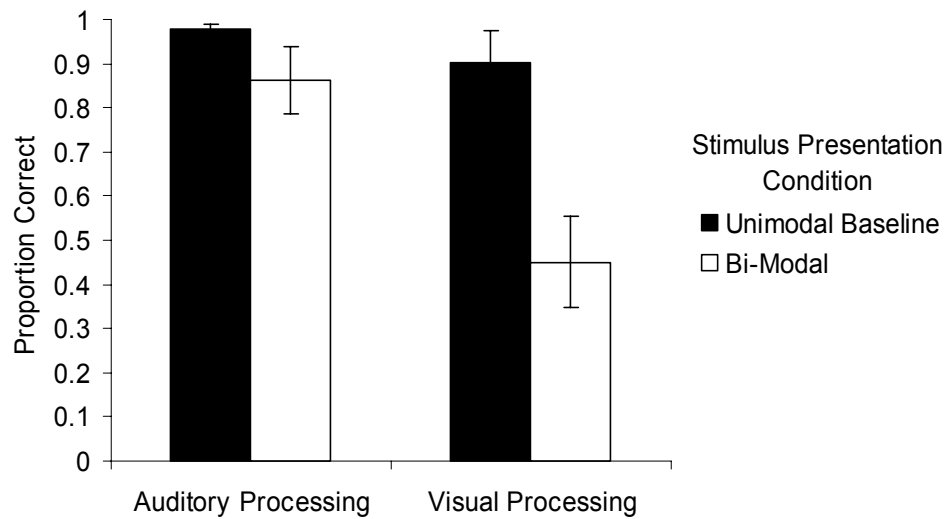


Figure 9. Proportion of Correct Responses in the Auditory Dominance Condition in Experiment 5.

In sum, in one condition, bi-modal presentation of stimuli attenuated processing of visual but not auditory input (i.e., auditory dominance effects), whereas in the other condition bi-modal presentation attenuated processing of auditory but not visual input (i.e., visual dominance effects). Therefore, the current experiment replicated both modality dominance effects found in previous research. Recall that auditory and visual dominance effects have comparable effect sizes, thus suggesting that any asymmetry found between auditory and visual dominance is unlikely to stem from the fact that the modality dominance effect in one modality is significantly weaker than the modality dominance effect in the other modality.

Having replicated both auditory and visual dominance effects, focus can turn to the question of whether participants can flexibly shift between visual and auditory

dominance. If participants can shift flexibly between auditory and visual dominance, this would suggest that modality dominance effects are comparably robust and relatively independent. Conversely, any asymmetry in shifting would indicate that the dominance of a given modality is a more robust phenomenon than the dominance of the other modality. This issue is addressed in Experiments 6-7.

EXPERIMENT 6A

Experiment 6A examined shifts in modality dominance by intermixing trials producing auditory dominance effects with trials producing visual dominance effects.

Method

Participants

Participants were 22 young children (M age = 4.50 years, SD = 0.30 years; 14 girls and 8 boys). Three additional children, who did not exhibit above-chance accuracy on control items, were not included in the reported sample and were not included in any analyses.

Materials

Stimuli were the same auditory-visual compounds used in Experiment 5. However, instead of the two bimodal sets of stimuli being presented as between-subjects conditions, they were intermixed and presented to all participants. Again, Visual Dominance Trials

paired Familiar Shapes and Unfamiliar Tone Patterns, and Auditory Dominance Trials paired Familiar Shapes and Familiar Sounds. The bimodal conditions of Experiment 5 served as unmixed baselines for Experiment 6A.

Design and Procedure

The experiment had a 2 (Trial type: Auditory Dominance vs. Visual Dominance) by 4 (Test item: $VIS_{Target}AUD_{Target}$, $VIS_{New}AUD_{New}$, $VIS_{New}AUD_{Target}$, and $VIS_{Target}AUD_{New}$) within-subjects design. The experiment included a total of 24 trials (2 Trial types, with 3 Targets per type, with 4 Test items per Target). Each trial was presented to participants the same way as described in Experiment 5. The presentation of trials always alternated between the Visual Dominance and Auditory Dominance Trials. However, which type of trial (i.e., Visual Dominance or Auditory Dominance) was presented as the first trial and the order of trial types (i.e., the 4 Test items) was random. An example of the possible first 4 trials is presented in Figure 10.

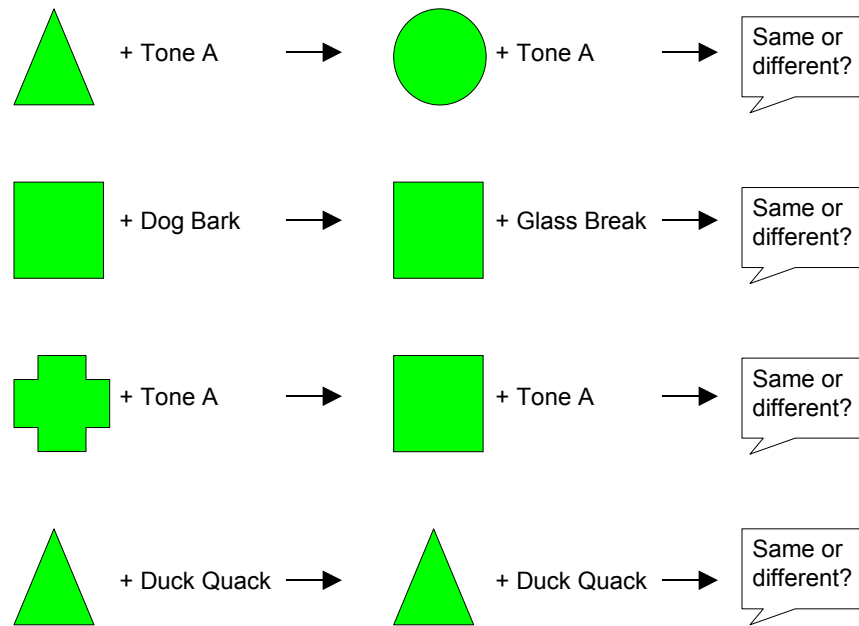


Figure 10. Example of possible first 4 trials in Experiment 6A.

Participants were given the same “matching game” instructions as those given for bimodal conditions in Experiment 5 (i.e., told that they would be shown a picture and a sound and then another picture and sound, and then be asked if the second one had the same picture and sound as the first one).

Results and Discussion

Participants were highly accurate in accepting $VIS_{Target}AUD_{Target}$ items and rejecting $VIS_{New}AUD_{New}$ items (with accuracy exceeding 93%). The remaining analyses will focus on encoding of visual information (i.e., accuracy on $VIS_{New}AUD_{Target}$) and on encoding of auditory information (i.e., accuracy on $VIS_{Target}AUD_{New}$ items). These data

are presented in Figure 11. Also in the figure are unmixed baselines – conditions where only auditory dominance trials or only visual dominance trials were presented. These baselines performances were derived from Experiment 5.

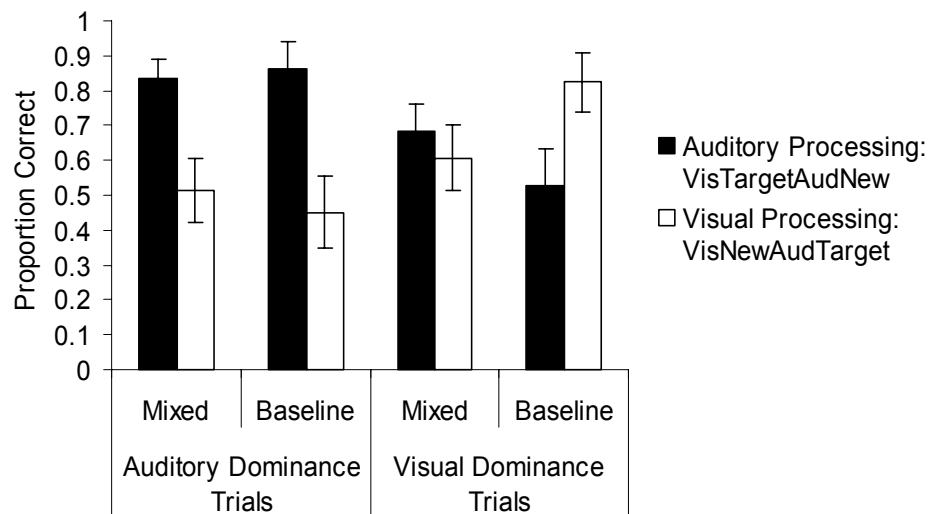


Figure 11. Proportion of Auditory and Visual Processing in the Auditory and Visual Dominance Trials for Experiment 6A.

Major analyses were focused on determining encoding of the auditory and visual modality for both Auditory Dominance Trials and Visual Dominance Trials by comparing each with their respective unmixed baselines. Two separate 2 (Condition: Baseline vs. Mixed) by 2 (Encoded Input: Visual vs. Auditory) mixed ANOVAs with encoded input as a repeated measure were conducted for the Auditory Dominance Trials and the Visual Dominance Trials. In the Auditory Dominance Trials, there were no appreciable differences between the Mixed Condition and the Baseline, with both the

main effect of condition and the interaction being non-significant, $F_s < 1$. At the same time, there was a significant main effect of encoded input, with participants being more likely to encode auditory than visual input, $F(1, 37) = 16.36, p < .0001$, partial Eta Squared = 0.307.

In contrast, in the Visual Dominance Trials, the ANOVA pointed to a significant interaction, $F(1, 35) = 6.29, p < .05$, partial Eta Squared = 0.15. Planned comparisons indicated that whereas there was greater processing of visual information than auditory information in the Baseline, $t(14) = 3.5, p < .005$, this was not the case for the Mixed Condition, $t < 1$.

Overall, mixing dominance trials had little effect on auditory dominance, whereas visual dominance attenuated greatly. In particular, on Auditory Dominance Trials of the mixed condition, participants ably processed auditory input (83.3%, above chance, one sample $t(21) = 5.84, p < .001$), whereas they failed to process visual information (51.5%, not different from chance, $p > .87$). At the same time, Visual Dominance Trials of the mixed condition pointed to a disappearance of the visual dominance effect: similar to Auditory Dominance Trials, participants failed to encode visual input (60.6%, not different from chance, $p > .28$), whereas they encoded auditory input (68.2%, above chance, one-sample $t(21) = 2.25, p < .03$).

In sum, results of Experiment 6A indicate that while the mixing of trials had little effect on auditory dominance, it resulted in the disappearance of visual dominance. These findings present evidence that there are greater effects of auditory dominance on visual dominance than the reverse, thus suggesting that auditory dominance is a more robust phenomenon than visual dominance.

One potential alternative explanation for the differences between auditory and visual dominance found in Experiment 6A is that auditory stimuli were more interesting and exciting because two different sets of sounds were used and visual stimuli were the same throughout the experiment. Experiment 6B examines this possibility.

EXPERIMENT 6B

Experiment 6B used the same intermixed design as Experiment 6A, however, in Experiment 6B there were two different sets of pictures (landscapes and familiar shapes), each paired with the same set of sounds (three-tone-patterns).

Method

Participants

Participants were 22 young children (M age= 4.57years, SD = 0.35years; 7 girls and 15 boys). An additional participant did not exhibit above-chance accuracy on control items and was not included in the analyses.

Materials, Design and Procedure

Similar to the previous experiments, auditory and visual stimuli were presented simultaneously. Visual Dominance Trials were identical to those used in Experiment 6A (Unfamiliar Tone Patterns paired with Familiar Shapes). Auditory Dominance Trials used stimulus sets previously found to produce auditory dominance (Napolitano & Sloutsky, 2003, Experiment 2 and 4). On these trials Unfamiliar Tone Patterns used in Experiment

6A were paired with Unfamiliar Landscapes. These visual stimuli were 10 cm x 10 cm in size digital photographs of different types of green colored foliage (see Napolitano & Sloutsky, 2003, Experiments 2 and 4, for examples of visual stimuli and details of discriminability calibration experiments). The procedure was similar to that in Experiment 6A.

Results and Discussion

Similar to Experiment 6A, participants were highly accurate in accepting $VIS_{Target}AUD_{Target}$ items and rejecting $VIS_{New}AUD_{New}$ items (with accuracy exceeding 94%). The analyses of auditory and visual processing revealed a pattern similar to Experiment 6A.

Similar to Experiment 6A, participants accurately processed auditory input on Auditory Dominance Trials (68.4% correct, above chance, one sample $t(21) = 2.23, p < .038$), while failing to process visual input (61.4% correct, not different from chance, $p = .235$). Also similar to Experiment 6A, Visual Dominance Trials pointed to a disappearance of the visual dominance effect: whereas participants failed to encode visual input (57.8%, not different from chance, $p = .47$), they did encode auditory input (68.4%, above chance, one-sample $t = 2.05, p = .056$).

These findings corroborated results of Experiment 6A: the intermixing of Auditory and Visual Dominance Trials resulted in the persistence of auditory dominance effects and the disappearance of visual dominance effects. These findings further suggest that there are greater effects of auditory dominance on visual dominance than the reverse, thus suggesting that auditory dominance is a more robust phenomenon than visual dominance.

Is it possible that mixing auditory and visual dominance trials confused participants, thus resulting in the disappearance of a less robust effect of visual dominance? Although this possibility does not undermine current findings, it seems necessary to further examine the asymmetry by somewhat simplifying the task. In particular, in Experiment 7, auditory and visual dominance trials were presented in blocks, with the order of blocks being a factor. First, it is possible that the asymmetry found in Experiment 6 would weaken or disappear, with modality dominating in the first block affecting modality dominance in the second block. Conversely, it is possible that the asymmetry found in Experiment 6 persists, with only the Auditory Dominance block affecting the Visual Dominance block. Finding this same asymmetry would further suggest that auditory dominance is a more robust phenomenon than visual dominance.

EXPERIMENT 7

Experiment 7 further examines the asymmetry between auditory and visual dominance found in Experiment 6 by presenting participants with blocks of trials. In one condition, an auditory dominance block preceded a visual dominance block, whereas in the other condition, a visual dominance block preceded an auditory dominance block.

Method

Participants

Participants were 50 young children (M age= 4.49 years, SD = 0.29 years; 29 girls and 21 boys). There were 2 between-participants conditions described below, with 25 children

participating in each condition. Five additional children also participated in Experiment 7, but they did not exhibit above-chance accuracy on control items. These children are not included in the reported sample and were not included in any analyses.

Materials, Design and Procedure

The experiment used the same Auditory and Visual Dominance Trials used in Experiments 5 and 6A. However, unlike Experiment 6A, Auditory and Visual Dominance Trials were not intermixed but were instead presented in two separate blocks within each condition.

Visual Dominance Block First Condition. In the Visual Dominance Block First Condition, the first block was comprised of Visual Dominance Trials used in Experiments 5 and 6A. The second block was comprised of Auditory Dominance Trials used in Experiments 5 and 6A.

Auditory Dominance Block First Condition. The Auditory Dominance Block First Condition was similar to the Visual Dominance Block First Condition, except that the order of blocks was reversed.

The experiment had a mixed design with the condition (Visual Dominance Block First vs. Auditory Dominance Block First) varying between participants, and the four test item types varying within participants. Again, participants were given the same “matching game” instructions as in Experiment 5.

The experiment included a total of 24 trials (2 blocks, with 3 Targets per block, with 4 Test item types per Target). In each condition the 12 trials of dominant modality block were presented first, followed immediately by the 12 trials of the non-dominant modality

block. Trials were presented in the same manner as in previous experiments, and the presentation order within each block of the 3 Targets and corresponding Test items was randomized.

Results and Discussion

Similar to Experiments 5-6, participants were highly accurate in responding to $VIS_{Target}AUD_{Target}$ and $VIS_{New}AUD_{New}$ items, with accuracy for each condition and block exceeding 85%. Participants' processing of auditory and visual input across conditions is presented in Figure 12. As can be seen in the figure, when Visual Dominance Trials were presented in the first block, auditory dominance persisted in the second block, with participants encoding auditory input (above chance, one-sample $t = 3.03$, $p < .006$), but not visual input (not different from chance, $p > .42$). In contrast, when Auditory Dominance Trials were presented in the first block, there was no evidence of visual dominance in the second block, with visual input eliciting chance processing ($p > .21$), but auditory input eliciting above chance processing (one-sample $t = 2.52$, $p < .019$).

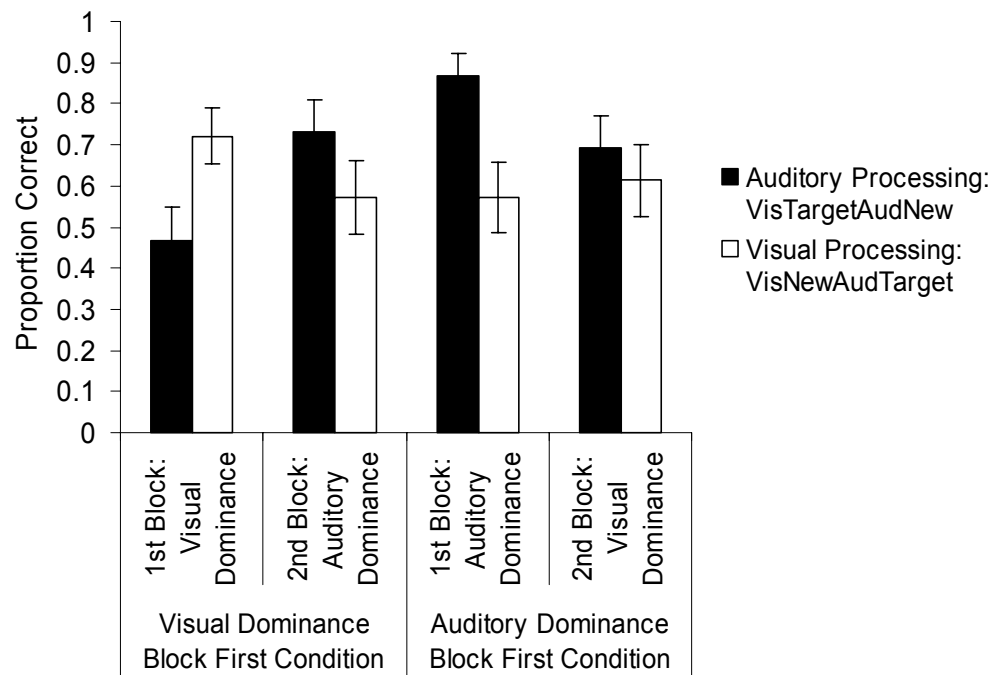


Figure 12. Proportion of Auditory and Visual Processing in the Auditory Dominance First and Visual Dominance First Conditions for Experiment 7.

These findings corroborate and further extend results of Experiment 6: similar to Experiment 6, there was a greater effect of auditory dominance on visual dominance than the reverse. Taken together results of Experiments 6-7 suggest that auditory dominance is a more robust phenomenon than visual dominance. This asymmetry is remarkable given that auditory and visual dominance effects were comparably strong as evidenced by comparable effect sizes reported in Experiment 5.

Overall, results of Experiments 6-7 indicate that participants can automatically shift from visual to auditory dominance but not from the auditory to visual dominance, thus suggesting that auditory input exerts a greater priming effect on subsequently presented

auditory input than visual input exerts on subsequently presented visual input. However, Experiments 6-7 used only manipulations that affect automatic attention. Can young children deliberately focus on non-dominant modality? Is there an asymmetry between the auditory and visual modalities? Answers to these questions would reveal a degree to which modality dominance is accessible to deliberate control, thus elucidating some important aspects of deliberate selective attention early in development. Thus, this issue was examined in Experiment 8.

EXPERIMENT 8

The goal of Experiment 8 was to examine the extent to which modality dominance effects can be changed by deliberately shifting attention from a dominant to a non-dominant modality. In Experiment 8, participants were presented with instructions requiring them to ignore the dominant modality while attending to the non-dominant modality.

Method

Participants

Participants were 34 young children (M age= 4.39 years, SD = 0.27 years; 18 girls and 16 boys). There were 2 between-participants conditions, with 17 children participating in each condition. An additional group of 9 children also participated in Experiment 8, but they did not exhibit above-chance accuracy on control items described below. These children are not included in the reported sample and were not included in any analyses.

Materials

Stimuli were the same as those used to create the Visual Dominance Condition and the Auditory Dominance Condition in Experiment 5, and again those two conditions were tested.

Design and Procedure

The experiment had a mixed design with instructions to ignore the dominant modality varying between participants, and the four test item types varying within participants. Again, participants were told that they would play a matching game, in which they would be shown a picture and a sound [an example was given at this point], and then another picture and sound [an example was given at this point]. They would need to decide if the second one was the same as the first one. If it was, they should answer SAME, whereas if it had a different sound in Condition 1 or a different picture in Condition 2 they should answer DIFFERENT. However, now the participants were also told that the computer would try to trick them by presenting pictures (Condition 1) or sounds (Condition 2). In order not to be tricked, they had to focus only on sounds (Condition 1) or only on pictures (Condition 2). Before the onset of the experiment, participants were again explicitly asked to ignore the visual stimulus (“Remember do not pay attention to the pictures”) in Condition 1 (Visual Dominance) or to ignore the auditory stimuli (“Remember do not pay attention to the sounds”) in Condition 2 (Auditory Dominance).

The experiment included a total of 12 trials (3 Targets, with 4 Test item types per Target). Stimuli were displayed the same way as was done in all previous experiments,

and again the presentation order of the three Targets and corresponding Test items were randomized.

Results and Discussion

Data were analyzed to determine whether participants were capable of ignoring the dominant modality and encoding the non-dominant modality. As in previous experiments, participants were exceedingly accurate (i.e., greater than 88%) in responding to $VIS_{Target}AUD_{Target}$ and $VIS_{New}AUD_{New}$ items.

To examine effects of instructions on auditory and visual dominance, participants' responses in the Auditory and Visual Dominance Conditions were compared to their respective No Instruction Baselines, which were patterns of performance derived from Experiment 5. Findings are presented in Figure 13. As can be seen in the figure, instructions to ignore the auditory modality had little effect on auditory dominance. Similar to the No Instruction Baseline, participants exhibited auditory dominance, with processing of auditory and visual input in the Auditory Dominance Condition not changing compared to the No Instruction Baseline (neither the main effect of instructions nor the interaction was significant, both $F_s < 1$, $p_s > 0.4$).

In contrast, instructions to ignore the visual modality resulted in a marked attenuation of visual dominance, with the main effect of instruction being significant, $F(1, 32) = 13.27$, $p < 0.05$, partial Eta-Squared = 0.29. More specifically, the visual dominance effect present in the No Instruction Baseline disappeared in the experimental condition. This asymmetry is especially important given that (as reported in Experiment 5) auditory and visual dominance effects were comparably strong.

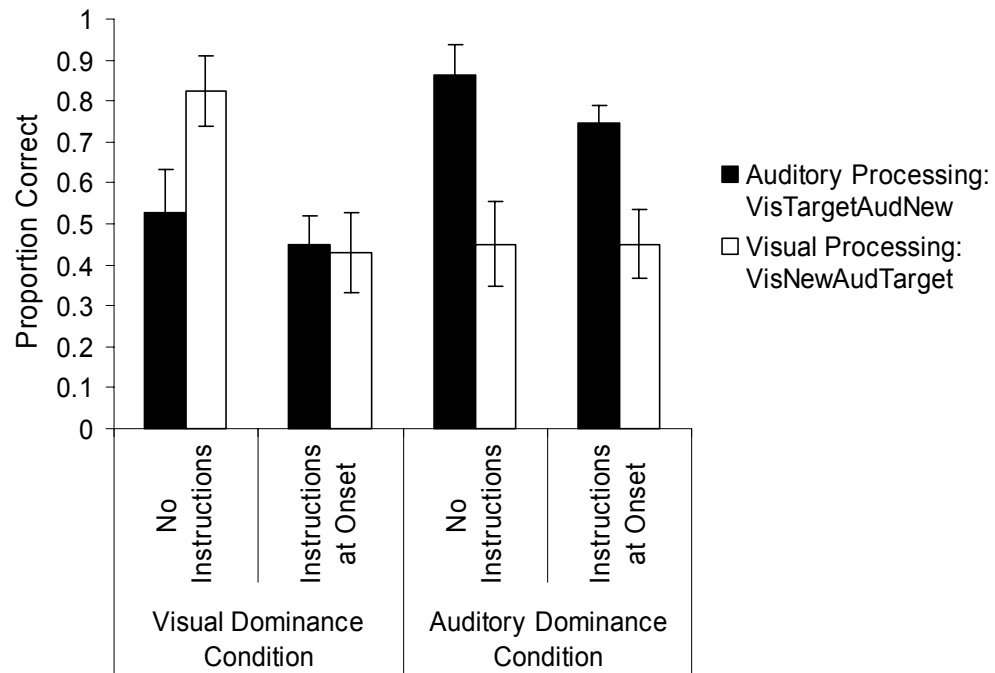


Figure 13. Proportion of Auditory and Visual Processing in the Auditory and Visual Dominance Conditions for Experiment 8.

To examine the ability to follow these instructions at a later point in development, a separate experiment was conducted with college undergraduates (13 participants per condition). Unlike young children, adults were at ceiling at ignoring the requested modality and attending to the other modality in both auditory and visual dominance conditions (in all conditions, participants were at 100% in following instructions to attend to a given modality and above 97% in ignoring a to-be-ignored modality). Therefore, adults had no difficulty in deliberately attending to either modality when instructed to do so.

In sum, child participants were more likely to respond to instructions in the Visual Dominance Condition than in the Auditory Dominance Condition. These findings further support the asymmetry between auditory and visual dominance. Similar to Experiments 6-7, auditory dominance was more robust than visual dominance.

These findings indicate that visual dominance effects can be attenuated deliberately (i.e., participants could follow instruction ignoring the modality in the visual dominance condition), whereas auditory dominance effects cannot be attenuated deliberately (i.e., participants were unable to follow instructions and focus on the visual modality in the auditory dominance condition). Results of Experiment 8 leave an important question unanswered: are young children capable of deliberately ignoring the dominant auditory modality under any conditions? It is possible that under more extreme conditions, for example under conditions in which instructions are repeated over the entire course of testing, young children may be capable of ignoring dominant auditory input. This possibility is tested in Experiment 9.

EXPERIMENT 9

Experiment 9 examines how instructions given to young children to ignore the dominant modality repeated on every trial affect attention to that dominant modality.

Method

Participants

Participants were 34 young children (M age= 4.33 years, SD = 0.33 years; 14 girls and 20 boys). There were 2 between-participants conditions, with 17 children participating in each condition. An additional group of 8 children also participated in Experiment 9, but they did not exhibit above-chance accuracy on control items described below. These children are not included in the reported sample and were not included in any analyses.

Design and Procedure

The design and procedure were similar to Experiment 8, with one difference: participants were instructed before the onset of each individual trial to focus on the sounds and ignore the pictures in the Visual Dominance Condition or to focus on the pictures and ignore the sounds in the Auditory Dominance Condition.

Results and Discussion

As in previous experiments, participants were exceedingly accurate (i.e., greater than 86%) in responding to $VIS_{Target}AUD_{Target}$ and $VIS_{New}AUD_{New}$ items. To examine effects of instructions on auditory and visual dominance, participants' responses in the Auditory and Visual Dominance Conditions were compared to their respective No Instruction Baselines. Findings are presented in Figure 14. As can be seen in the figure, instructions to ignore the dominant modality affected both auditory and visual dominance. In particular, both the Auditory Dominance and the Visual Dominance Conditions reversed compared to their respective baselines, with both interactions being significant, both F s >

7.5, $ps < .05$, both partial Eta-squared > 0.19 . These results indicate that when instructions were repeated on every trial, the instructions did affect participants' responses.

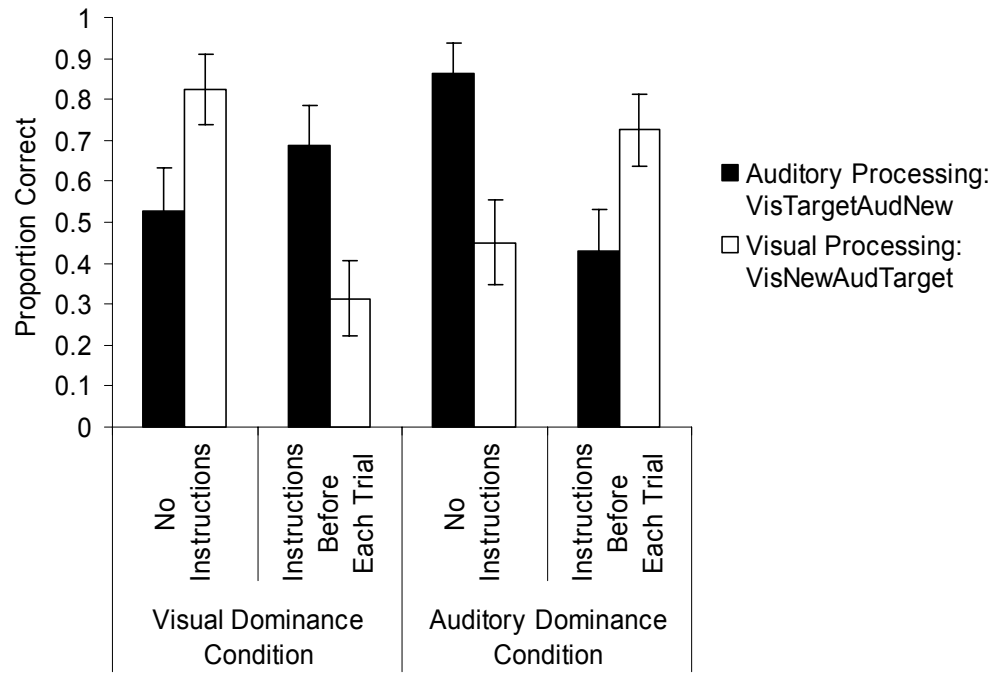


Figure 14. Proportion of Auditory and Visual Processing in the Auditory and Visual Dominance Conditions for Experiment 9.

At the same time, in the auditory dominance condition, on 43% of trials participants failed to follow instructions to ignore the auditory modality, and in the visual dominance condition, on 31% of trials participants failed to follow instructions to ignore the visual

modality. Therefore, even when instructions were repeated on every trial, participants often failed to ignore the dominant modality.

To further examine this phenomenon, the accuracy of processing of the non-dominant modality in the current experiment was compared with the accuracy of processing of the non-dominant modality in a unimodal baseline of Experiment 5. Accuracy was calculated as the proportion of hits (the proportion of correct “Same” responses) and false alarms (i.e., the proportion of erroneous “Same” responses). If participants follow instructions completely and ignore the dominant modality while focusing on the non-dominant modality, accuracy of processing of the non-dominant modality should not differ from its respective unimodal baseline.

As can be seen in Figures 15-16, in both conditions, proportions of hits was smaller and the proportion of false alarms was greater than in the respective unimodal baselines. This was confirmed in two separate mixed ANOVAs, with both pointing to significant condition by response type interactions, $F(1, 32) = 8.3, p < .01$, partial Eta-Squared = 0.21, for the Auditory Dominance Condition, and $F(1, 31) = 8.64, p < .01$, partial Eta-Squared = 0.22, for the Visual Dominance Condition. Therefore, while the participants did follow instructions, they could not completely ignore the dominant modality – if they could, accuracy of processing of the non-dominant modality should not have differed from its unimodal baseline. These findings reveal important limitations of deliberate attention early in development: even in the most radical condition of instructions repeated on every trial, participants could not completely ignore the dominant modality. This interference of the dominant modality further suggests that modality dominance effects stem from automatic pulls on attention.

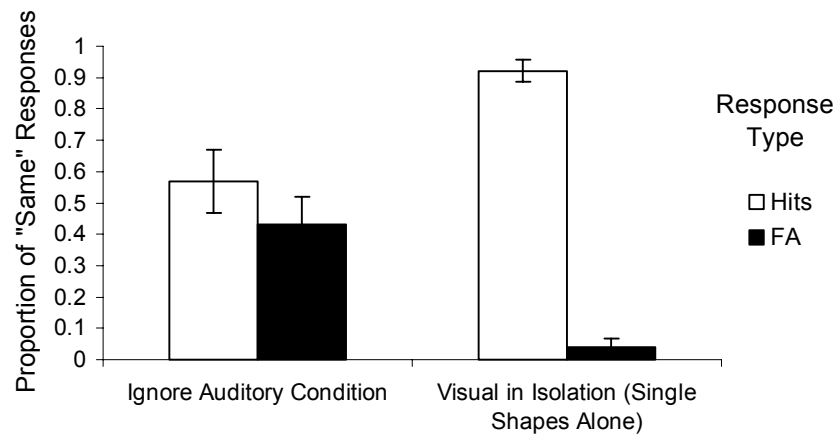


Figure 15. Processing of Visual Information (i.e., Proportions of Hits and False Alarms) Under the Instructions to Ignore Auditory Information and in the Unimodal Visual Baseline for Experiment 9.

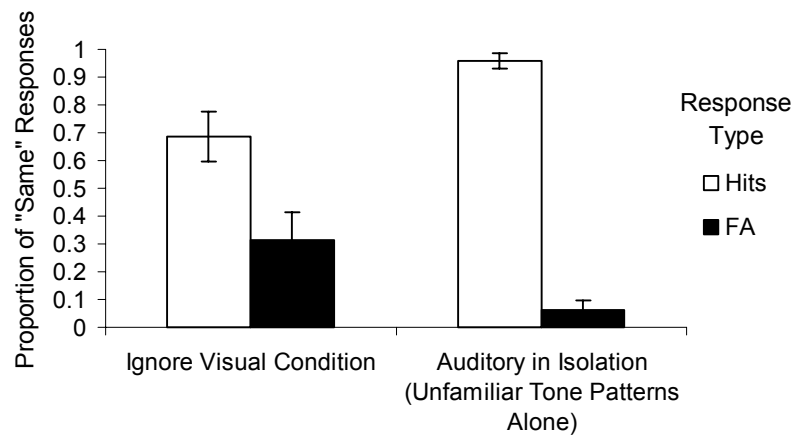


Figure 16. Processing of Auditory Information (i.e., Proportions of Hits and False Alarms) Under the Instructions to Ignore Visual Information and in the Unimodal Auditory Baseline for Experiment 9.

SUMMARY

The experiments presented in this second phase of research were conducted in order to examine the extent to which modality dominance is automatic and the extent to which modality dominance is deliberately controlled. Experiment 5 replicated and further extended the earlier reported modality dominance effects by demonstrating that processing of non-dominant (but not the dominant) modality attenuates compared to its unimodal baseline. Experiments 6-7 pointed to an asymmetry between auditory and visual dominance: participants can switch from visual to auditory dominance, whereas they experience difficulty switching from auditory to visual dominance. Across the conditions, auditory dominance remained strong, whereas visual dominance attenuated or disappeared. These findings suggest that there are greater effects of auditory dominance on visual dominance than the reverse, thus suggesting that auditory dominance is a more robust phenomenon than visual dominance. The asymmetry was further supported in Experiment 8, where participants were instructed to focus on the non-dominant modality, while ignoring the dominant modality. Results indicate that participants were more likely to respond to instructions in the visual dominance condition than in the auditory dominance condition. As mentioned above, these asymmetries are remarkable given that auditory and visual dominance effects were comparably strong (see Experiment 5). Finally, in Experiment 9, instructions to ignore the dominant modality were repeated on every trial. This time, the modality dominance was reversed for both modalities, although there was substantial interference of the dominant modality, with young

children being unable to completely ignore the dominant modality. These findings further suggest that modality dominance stems from automatic pulls on attention and underscore the difficulty of ignoring automatically detected information early in development.

Overall, the results point to an asymmetry between auditory and visual dominance: whereas the experience of visual dominance had little or no effect on auditory dominance, the experience of auditory dominance resulted in the disappearance of visual dominance effects. Furthermore, instructions to ignore the dominant modality are more likely to eliminate visual dominance than auditory dominance. This asymmetry supports the idea that auditory dominance is a developmental default, suggesting that auditory dominance is more automatic and less deliberate than visual dominance. Also, these findings point to important limitations of deliberate attention early in development: the dominant modality automatically engages attention and participants cannot fully ignore the dominant modality.

Thus far the two phases of research elucidate important aspects of the role of attention in cross-modal processing and provide suggestive evidence that modality dominance effects may have implications for conceptual development. Specifically, the results of Chapter 2 suggest that label effects may be driven in part by general auditory effects and in part by familiarity effects, and the results of this Chapter suggest that because the attention to auditory-visual input is automatic and not under deliberate control, young children may not control what information affects their judgments. Therefore, the role of modality dominance effects in young children's conceptual judgments is the focus of the third phase of research presented in Chapter 4.

CHAPTER 4

MODALITY DOMINANCE EFFECTS IN CATEGORIZATION

Recall that auditorily presented linguistic labels often play an important role in young children's conceptual organization and thinking. In particular, when two entities share a label, young children tend to perceive these entities as looking more alike (Sloutsky & Lo, 1999; Sloutsky & Fisher, 2004), to group these entities together (Sloutsky & Fisher, 2004), and to induce non-obvious properties from one entity to another (Gelman & Markman, 1986; Sloutsky & Fisher, 2004; Welder & Graham, 2001).

Also recall that two classes of explanations of the role of linguistic labels in conceptual and semantic tasks have been proposed, one arguing that effects of labels can be explained by the fact that labels are linguistic stimuli and one arguing that the effects of labels can be explained by attentional features.

The language-specific proposal has two variants, semantic and prosodic. The semantic proposal argues that the effects of linguistic labels stem from two important assumptions that young children hold: (a) they assume that entities are members of categories, and (b) they assume that labels presented as count nouns convey category membership (Gelman & Coley, 1991). These assumptions lead young children to infer that entities that are denoted by the same count noun belong to the same category

(Gelman & Markman, 1986; Markman, 1989; see also Waxman & Markow, 1995, for a discussion). The prosodic proposal argues that facilitative effects of linguistic labels might not be limited to semantic effects, but that additional effects might be due to infants' and young children's special attention to the prosodic components of human speech which distinguish speech from other sounds (Balaban & Waxman, 1997). However, while there is evidence to support the contention that linguistic stimuli are privileged in cognitive tasks, this evidence could be confounded with the effects of audition and familiarity.

The attentional proposal (see Sloutsky & Napolitano, 2003, for a variant of this proposal) argues that effects of labels might not be limited to language-specific factors, but that these effects may also stem from input that engages attention first (auditory and familiar input, including linguistic labels) partially overshadowing corresponding input that is subsequently processed. Thus, as a result of auditory overshadowing, processing of visual input attenuates, and this is enough to give the fully processed auditory or familiar input a slight edge over the visual input.

If the effects of labels are driven by attentional factors, other types of auditory input that are capable of overshadowing their corresponding visual input should promote categorization (and also induction), and these effects should be similar to what is produced by count nouns. This should not be the case if effects of labels stem solely from semantic effects (or alternatively phonetic effects).

While the modality dominance effects produced in the previous chapters, as well as in previous research (Sloutsky & Napolitano, 2003; Napolitano & Sloutsky, 2003; Robinson & Sloutsky, 2004) may have important implications for research on young children's

conceptual development, their role in conceptual development has not been examined directly. Thus, the experiments presented herein are a first step in examining the role of modality dominance in conceptual development.

In what follows, I explore the different effects of different types of auditory stimuli. In all experiments young children were introduced to triads of stimuli on a laptop screen and then were asked to guess whether the Target was the same kind of animal as the Test Item A (which shared the same label) or Test Item B (which shared the same picture). Experiment 10 establishes the effects of nonsense count nouns on categorization performance. Experiments 11-12 substitute count nouns with vowel patterns that do not resemble English labels. Experiments 13-14 substitute count nouns with either familiar or unfamiliar nonspeech sounds.

Since I have argued that the effects of labels may stem from input that receives privileged processing (auditory input mediated by the familiarity of input) being processed before corresponding input that is not privileged, the following outcomes are predicted: 1) linguistic input effects should not differ from the effects of other types of familiar auditory input, and 2) when auditory input is less familiar than visual input, the effects of sounds should disappear.

EXPERIMENT 10

In order to determine the effects of spoken labels that resemble English count nouns, participants were presented with nonsense count noun labels for animal pictures and

asked to determine which animals are of the same kind (Sounds Presented Condition). Their responses were compared to a separate sample who did not receive labels (No Sound Baseline Condition).

Method

Participants

Participants were 40 young children (M age= 4.44 years, SD = 0.26 years; 20 girls and 20 boys). There were 2 between-participants conditions described below, with 20 children participating in each condition.

Materials

Stimuli consisted of 4 practice and 10 test picture-“label” triads. All 4 of the practice triads included two items (Test Item A and Test Item B) that did not share perceptual similarity or label, and a third item (Target) that shared a label with Test Item A and perceptual similarity with Test Item B. Five of the 10 test triads (Conflict Triads) included two items (Test Item A and Test Item B) that did not share perceptual similarity or label, and a third item (Target) that shared a label with Test Item A and perceptual similarity with Test Item B. The other 5 triads (No Conflict Triads) served as control items and did not pit perceptual similarity against shared label; They included two Test

items that were both equal in perceptual similarity to the Target, but one of the items shared a common label (Test Item A) and one had a different label (Test Item B).

Pictures. Pictures for the practice trials were highly recognizable photographs of cats and dogs. Pictures for test trials were close-up portrait photographs of unusual animals, such as a porcupine and a cuscus. These are the same unfamiliar animal stimuli used in Experiment 2, which children reported they recognized on 58% of trials and attempted to label on 47% of trials (see Experiment 2 for further details). Each picture triad set for a Conflict Trial included test stimuli of two different animals (e.g. Cuscus face versus Tasmanian devil face) that were perceptually distinct. Figure 17 is an example of a triad set for a Conflict Trial. Each picture triad for a No Conflict Trial included identical pictures of the same animal (e.g. Tasmanian devil face vs. Tasmanian devil face). Figure 18 is an example of a triad set for a No Conflict Trial.

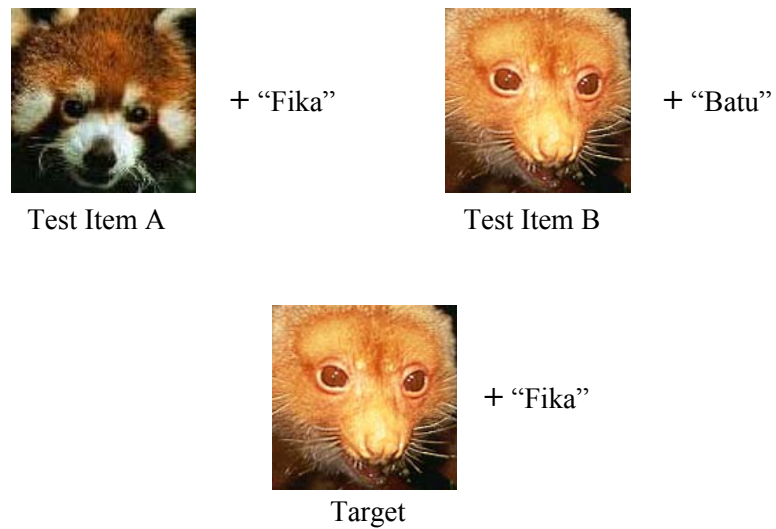


Figure 17. An example of the stimulus sets used in a Conflict Trial in the Sounds Presented Condition for Experiment 10.

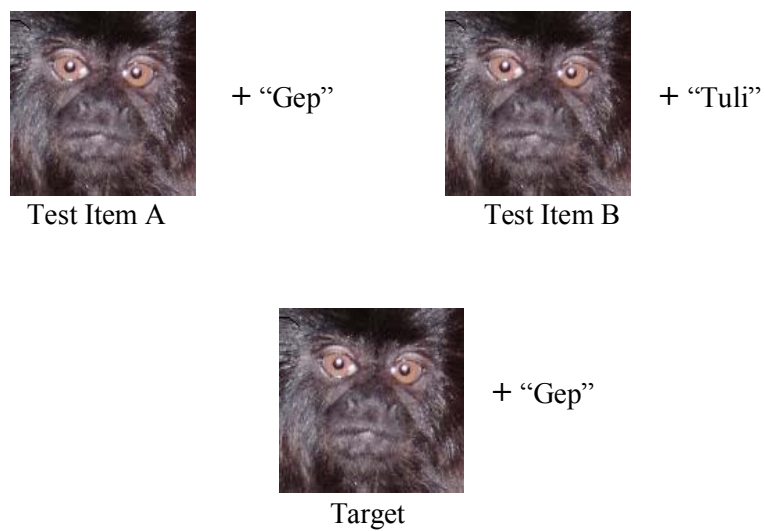


Figure 18. An example of the stimulus sets used in a No Conflict Trial in the Sounds Presented Condition for Experiment 10.

Labels. The labels for practice triads were “cat” and “dog”. The labels for test triads were two-syllable nonsense words, such as “fika” or “batu” that resembled English nouns. Both the discriminability and familiarity (of the source) of nonsense nouns were established in Experiment 4 (both $M > 96\%$).

Design and procedure

The experiment had a mixed design with the condition (Sounds Presented vs. No Sound Baseline) varying between participants, and the two triad types (Conflict vs. No Conflict) varying within participants.

There were a total of 14 trials: 4 practice “cat versus dog” trials and 10 test trials. Participants were tested using a Dell laptop individually in a quiet room within their daycare centers by a female experimenter. Participants were told they were going to play a matching game, and after a detailed description of the rules, they were told they would first start by doing some “practice tries” to make sure they understood the game. After all four practice trials, children were told they did a good job and that now they would play the real game with pictures of animals from another planet (and were also told the animals had funny names in the Sounds Presented Condition). The side of the screen Test Items A and B appeared on was randomly counterbalanced, and the side of the screen the experimenter pointed to first was counterbalanced. The order of test trials was random.

Sounds Presented Condition. Stimuli for all trials were presented in the following manner. Each trial started with a screen that showed three different animal photographs: one in the top right corner of the screen, one in the top left corner of the screen, and one

centered across the bottom half of the screen. Each trial's presentation began with the experimenter pointing to the first test item and saying "This is a batu". Next the experimenter pointed to the second test item and said "This is a fika". Finally, the experimenter pointed to the target and said "This is a batu". The experimenter then asked the participant "Do you think this animal (points to target) is the same kind of animal as this one (points to upper right animal) or this one (points to upper left animal)". The experimenter then recorded the participant's response, and followed with the next trial.

No Sound Baseline Condition. The baseline condition differed from the experimental Sounds Presented Condition in that no "labels" were presented during trials, and thus participants could only make selections based on visual similarity. The first trial began with the experimenter pointing to the first test item and saying "Look here". Next the experimenter pointed to the second test item and said "Look here". Finally, the experimenter pointed to the target and said "Look here". The experimenter then asked the participant "Do you think this animal (points to target) is the same kind of animal as this one (points to first test item) or this one (points to second test item)". The experimenter then recorded the participant's response, and followed with the next trial.

For both conditions participants were given positive verbal feedback and a small toy as a reward for their participation after all trials were completed.

Results and Discussion

The percentage of Test Item A (shared label) responses is presented in Figure 19. Participant selections in both Conflict and No Conflict Trials for the Sounds Presented

Condition were compared with those in the No Sound Baseline Condition. As seen in the figure, while the percentage of choices for Test Item A were at chance in the baseline for No Conflict Trials, $t(19) = 0.2, p < 0.84$, when vowel-patterns were presented, participants selections were significantly above-chance, $t(19) = 5.75, p < 0.001$. Furthermore, in Conflict Trials, participants selections for Test Item A increased by 19% when vowel-patterns were presented as compared to the No Sound Baseline.

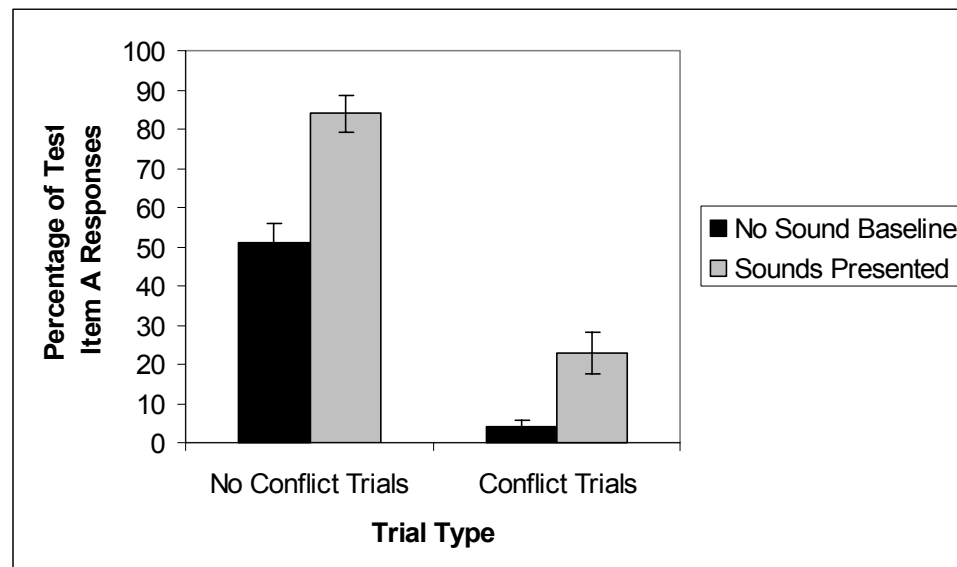


Figure 19. Percentage of Test Item A responses in Experiment 10.

To determine if the differences between the Conflict and No Conflict Trials and the differences between the Sounds Presented and No Sound Baseline Condition were significant, the proportion of selections for Test Item A were subjected to a mixed 2 (Condition) by 2 (trial type: Conflict and No Conflict) ANOVA with the trial type as a repeated measure. There was a significant main effect of trial type, $F(1, 38) = 101.2, p < 0.001$, partial Eta-Squared = 0.727. More importantly, there was a significant main effect

of Condition, $F(1, 38) = 23.29, p < 0.001$, partial Eta-Squared = 0.38, which indicated that introduction of a label did change categorization performance of young children. Thus, the analyses demonstrated that 1) when visual information was all the same (No Conflict Trials), participants were more likely to make Test Item A choices, and 2) even when the Test Item B was the only perceptual match (Conflict Trials), when labels were present, Test Item B choices attenuated significantly from the No Sound Baseline.

Overall, when children were presented with nonsense labels resembling English count nouns, there was effect of sounds, such that when animal pictures are accompanied by labels, children become less likely to rely on perceptual similarity in categorization. Now that the effect sizes for nonsense count nouns have been established, attention can be turned to whether other sounds can produce similar effects.

Experiment 3 established that unfamiliar linguistic stimuli (three-vowel-patterns) may have an advantage over somewhat familiar visual stimuli (familiar single shapes, but not familiar animals) because linguistic stimuli stem from a highly familiar source (i.e., human speech) and as such are capable of overshadowing visual input. While the semantic hypothesis argues that count nouns specifically are used in conceptual judgments, it seems possible that vowel sequences which had effects similar to the count nouns in the immediate recognition task (see Experiments 3 and 4), may produce similar effects to count nouns on this task. Alternatively, it is possible that vowel sequences do not affect young children's categorical judgments. Experiment 11 tests these possibilities.

EXPERIMENT 11

Experiment 11 examined whether young children would use vowel patterns, which do not resemble the structure of English count nouns to categorize animal photographs when the vowel patterns were presented as labels.

Method

Participants

Participants were 20 young children (M age= 4.56 years, SD = 0.27 years; 11 girls and 9 boys).

Materials

Stimuli consisted of the same 4 practice and 10 test picture-“label” triads used in the Sounds Presented Condition in Experiment 10, with the following difference: instead of the nonsense labels presented in test and control triads, labels for these triads were spoken 2-vowel-sequences, such as “a-e” or “o-o”. Again, familiarity was established using the source attribution task (see Experiment 3 for a full description). A different sample of 10 4-year-olds was tested and correctly attributed 2-vowel-sequences to a human on over 95% of trials.

Design and procedure

The design and procedure was the same as that used in the Sounds Presented Condition of Experiment 10.

Results and Discussion

The percentage of Test Item A responses is presented in Figure 20. As in Experiment 10, participant selections in both Conflict and No Conflict Trials were compared with those in the No Sound Baseline Condition. This baseline performance was derived from Experiment 10. As seen in the figure, participants selections were significantly above-chance in No Conflict Trials when vowel-patterns were presented, $t(19) = 6.49, p < 0.001$. Furthermore, in Conflict Trials, participants selections for Test Item A increased by 18% when vowel-patterns were presented as compared to the No Sound Baseline.

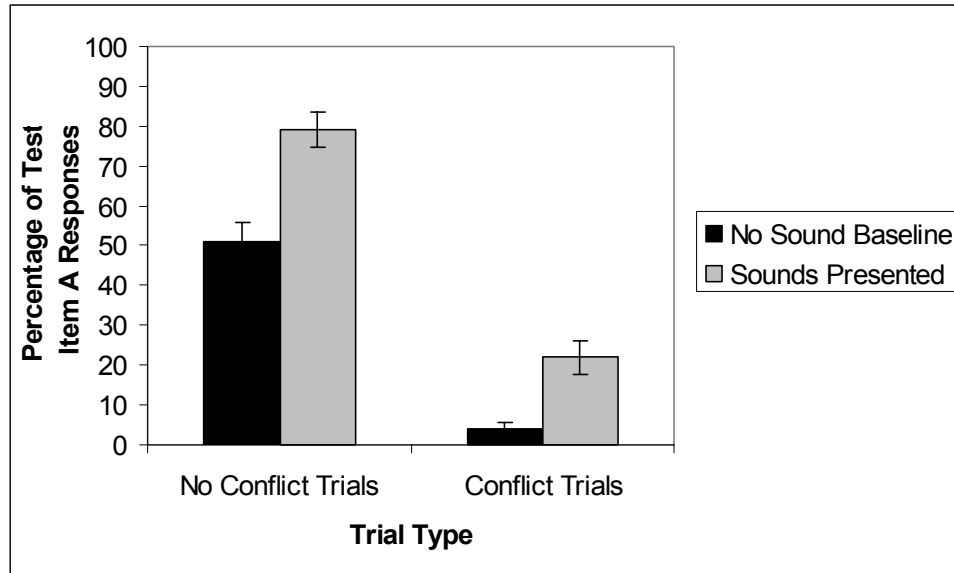


Figure 20. Percentage of Test Item A responses in Experiment 11.

Again the proportion of selections for Test Item A were subjected to a mixed 2 (Condition) by 2 (trial type: Conflict and No Conflict) ANOVA with the trial type as a repeated measure. As in Experiment 10, the same pattern of effects were found: there was a significant main effect of trial type, $F(1, 38) = 179.6, p < 0.001$, partial Eta-Squared= 0.83, and there was a significant main effect of Condition, $F(1, 38) = 29.26, p < 0.001$, partial Eta-Squared= 0.43.

Overall, when children were presented vowel-patterns that do not resemble English nouns, there was an effect of sounds, and this is a similar pattern of effects as those found using nonsense count nouns in Experiment 10. Thus, because nonsense count nouns and vowel patterns produce similar effects, it does not appear that noun structure is what is driving the effect of sounds on the task. However, although the “labels” did not resemble

actual count nouns, perhaps presenting them in a referential framework contributed to their acceptance as count nouns. In other words, although the sounds do not have count noun structure, the sounds are treated as count nouns by the experimenter. As a result, children readily accept them as nouns, and this may driving their effect. It is unclear if the effects would persist if the element of reference was removed, and sounds were instead presented in a nonreferential fashion. If the effect of sounds can be explained by the attentional factors of the sounds, then a referential framework should not be required to produce these demonstrated sound effects. Alternatively, if children select sounds because of their appreciation for the experimenter's intent to label these pictures with the vowel sounds, then effects of sounds should disappear when reference is removed. These possibilities are examined in Experiment 12.

EXPERIMENT 12

Experiment 12 examined whether young children would use auditory input used in Experiment 11 (vowel patterns) to categorize animal photographs when the auditory input was presented as the sounds that the animals like.

Method

Participants

Participants were 20 young children (M age= 4.45 years, SD = 0.29 years; 11 girls and 9 boys).

Materials, design, and procedure

Materials, design, and procedure were identical to Experiment 11, with the following exceptions: 1) instead of 2-vowel-patterns being presented as the animal names, they were presented as the sounds the animals like, and 2) the practice trials used “whoosh” and “boom” instead of “cat” and “dog”. In each trial the experimenter pointed to the first test item and said “This animal likes e-o”. Next the experimenter pointed to the second test item and said “This animal likes a-a”. Finally, the experimenter pointed to the target and said “This animal likes a-a”. The experimenter then asked the participant “Do you think this animal (points to target) is the same kind of animal as this one (points to first test item) or this one (points to second test item)”.

Results and Discussion

The percentage of Test Item A responses is presented in Figure 21. Again, participant selections in both Conflict and No Conflict Trials were compared with those in the No Sound Baseline Condition. This baseline performance was derived from Experiment 10. As seen in the figure, participants selections were significantly above-chance when vowel-patterns were presented in the No Conflict Trials, $t(19) = 5.59, p < 0.001$. Furthermore, in Conflict Trials, participants selections for Test Item A increased by 22% when vowel-patterns were presented as compared to the No Sound Baseline.

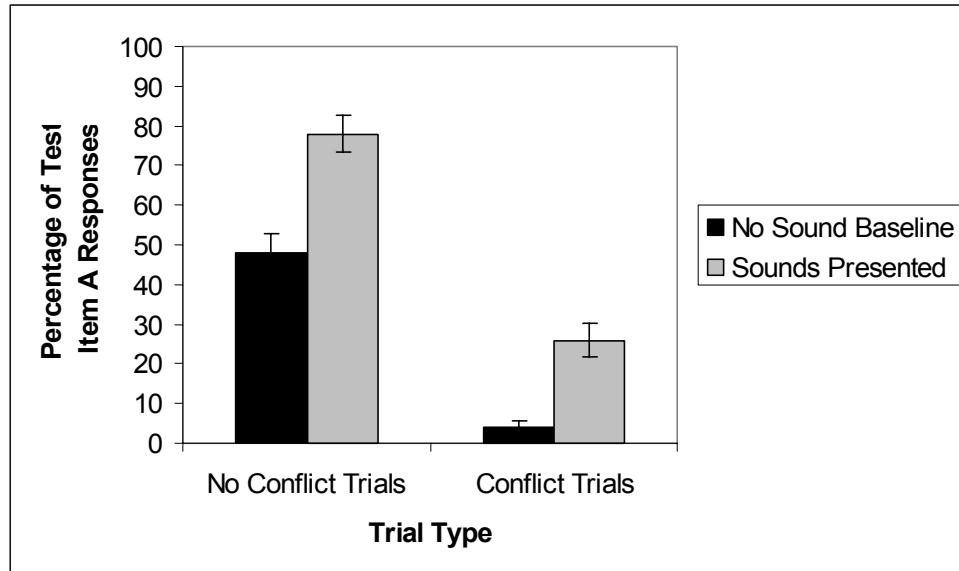


Figure 21. Percentage of Test Item A responses in Experiment 12.

Again the proportion of selections for Test Item A were subjected to a mixed 2 (Condition) by 2 (trial type: Conflict and No Conflict) ANOVA with the trial type as a repeated measure. As in Experiments 10 and 11, the same pattern of effects were found: there was a significant main effect of trial type, $F(1, 38) = 93.58, p < 0.001$, partial Eta-Squared= 0.71, and there was a significant main effect of Condition, $F(1, 38) = 27.14, p < 0.001$, partial Eta-Squared= 0.42.

Again, although the sounds do not resemble labels and were not presented within a referential context, the effect of sounds still persisted. These effects are quite striking considering that the sounds were presented as “sounds they animals like”, and therefore provided no basis for a causal link between Test Item A and the Target. Thus, neither semantic effects of sounds or referential intent appear to be driving these effects.

However, it is possible that even though the young children are told the vowel-patterns are just sounds the animals like, since they recognize the sounds as speech, they automatically assume they are labels.

To determine whether children's auditory selections were based on a belief that these sounds are labels, and thus made selections that favored sounds for this reason, a different set of 20 4-year-olds were tested to find out what the children believe the sounds are when they are not told anything by the experimenter. Participants were asked to guess whether the sounds were: a) the experimenter speaking another language, b) the experimenter imitating an animal, c) the experimenter imitating a machine, or d) they do not know. Overall, children were above chance in selecting animal sounds (46.7%) and at chance in selecting another language (25%). Thus, the auditory effects were not likely due to a belief that the sounds really are labels, as young children were most likely to assume the sounds were humans imitating animals. However, while this finding indicates that young children do not perceive these sounds as labels, it does not eliminate the possibilities that the young children are using the sounds because of their phonetic properties (see the phonetic proposal presented in Chapter 1 for a detailed account) or simply because they are human produced. Also, this finding produces an additional possibility, as it could be argued that a sound produced by an animal may be considered a causal property of the animal by young children, and thus effects persisted for this reason. Experiment 13 addresses these possibilities.

EXPERIMENT 13

Experiment 13 examined whether young children would use familiar machine sounds to categorize animal photographs when the auditory input was presented as the sounds that the animals like.

Method

Participants

Participants were 20 young children (M age= 4.62 years, SD = 0.22 years; 8 girls and 12 boys).

Materials, design, and procedure

Materials, design, and procedure were identical to the Experiment 3 with two exceptions. First, sounds were familiar machine sounds (e.g., telephone ring, breaking glass, car horn) produced by the computer. These sounds are a subset of the familiar sounds used in Experiments 1 and 2. Previous calibration (see Napolitano & Sloutsky, for a full description) found them to be both highly discriminable (M =97%) and highly familiar (M =90%). Second, sounds were produced by the computer instead of the experimenter, and this difference lead to a slightly modified presentation. For each trial the experimenter pointed to the first test item and said “This animal likes” and pushed a key to play the corresponding sound. Next the experimenter pointed to the second test item and said “This animal likes” and pushed a key to play the corresponding sound.

Finally, the experimenter pointed to the target and said “This animal likes” and pushed a key to play the corresponding sound. The experimenter then asked the participant “Do you think this animal (points to target) is the same kind of animal as this one (points to first test item) or this one (points to second test item)”.

Results and Discussion

The percentage of Test Item A responses is presented in Figure 22. Again, participant selections in both Conflict and No Conflict Trials were compared with those in the No Sound Baseline Condition, and this baseline performance was derived from Experiment 10. As seen in the figure, participants selections were significantly above-chance in No Conflict Trials when vowel-patterns were presented, $t(19) = 6.13, p < 0.001$. Furthermore, in Conflict Trials, participants selections for Test Item A increased by 28% when vowel-patterns were presented as compared to the No Sound Baseline.

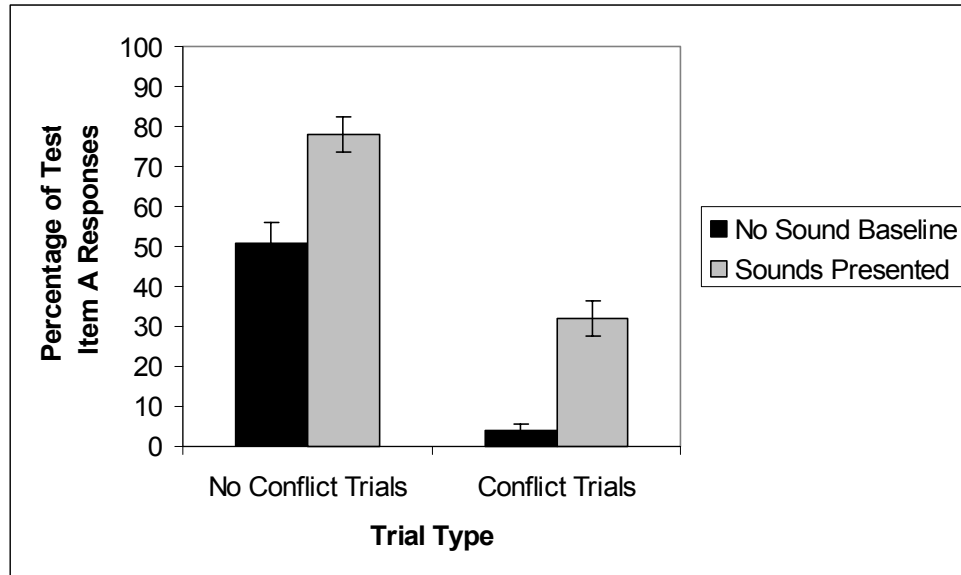


Figure 22. Percentage of Test Item A responses in Experiment 13.

Again the proportion of selections for Test Item A were subjected to a mixed 2 (Condition) by 2 (trial type: Conflict and No Conflict) ANOVA with the trial type as a repeated measure. As in previous experiments (Experiments 10-12), the same pattern of effects were found: there was a significant main effect of trial type, $F(1, 38) = 109.9, p < 0.001$, partial Eta-Squared= 0.74, and there was a significant main effect of Condition, $F(1, 38) = 21.28, p < 0.001$, partial Eta-Squared= 0.37.

Overall, there was an effect for familiar machine sounds, and these effects followed the same pattern as the effects of linguistic sounds. These effects severely undermine the argument that children rely on sounds only when sounds have a speech component, when they produced by humans, or when they refer to a potentially essential property of the

animal (i.e., the sound is produced by the animal). Furthermore, these effects support the attentional account, as the sounds are more familiar than the pictures they accompany.

Thus far the sounds presented in Experiments 10-13 have all affected the processing of visual input similarly. These findings corroborate the findings of modality dominance, as these sounds have been established to overshadow unfamiliar animals (see Experiment 2) or would be predicted to overshadow the unfamiliar animal pictures based on relative levels of familiarity. Thus, while these findings are not predicted by any linguistic account (i.e., semantic or prosodic hypothesis), these findings are predicted by the attentional hypothesis.

However, these findings also generate another possible explanation, as they may serve as evidence that children are simply affected by the “noise” created by the presentation of sounds, and thus are unable to block out task irrelevant information. Therefore, sounds may simply serve as a tie-breaker. If this is the case, then any type of auditory input should produce these effects. To test this possibility it is necessary to determine the effects a set of sounds that are unable to overshadow the unfamiliar animal pictures in immediate recognition has on this same categorization task. If similar effects are found for less familiar sounds, then such results would indicate that children are simply distracted by the noise presenting sounds creates. Experiment 14 tests this possibility.

EXPERIMENT 14

Experiment 14 examined whether young children would use sounds to categorize, when sounds are used that are not capable of producing auditory overshadowing when the sounds are paired with the unfamiliar animals.

Method

Participants

Participants were 20 young children (M age = 4.62 years, SD = 0.22 years; 14 girls and 6 boys).

Materials, design, and procedure

Materials, design, and procedure were identical to the Experiment 13 with the following exception: Auditory stimuli were unfamiliar computer-generated tone patterns, each consisting of three unique simple tones. These are the same tone patterns used in previous research (Sloutsky & Napolitano, 2003; Napolitano & Sloutsky, 2003). Previous calibration established that while the sounds were highly discriminable ($M > 96\%$), they were not familiar ($M < 17\%$). Simple tones varied on timbre (sine, triangle, or sawtooth) and frequency (between 1 Hz and 100 Hz). Each simple tone was 0.3 seconds in duration and was separated by .05 seconds of silence, with total pattern duration of 1

second. The average sound level of the tone patterns was 67.8 dB (with a range from 66 dB to 72 dB), which is comparable with the sound level of human voice in a regular conversation.

Results and Discussion

The percentage of Test Item A responses is presented in Figure 23. Again, participant selections in both Conflict and No Conflict Trials were compared with those in the No Sound Baseline Condition, and this baseline performance was derived from Experiment 10. As seen in the figure, the percentage of choices for Test Item A were at chance in the No Conflict Trials when tone-patterns were presented, $t(19) = 1.2, p = 0.213$. Also, in Conflict Trials, participants' selections for Test Item A did not increase from the No Sound Baseline.



Figure 23. Percentage of Test Item A responses in Experiment 14.

Again the proportion of selections for Test Item A were subjected to a mixed 2 (Condition) by 2 (trial type: Conflict and No Conflict) ANOVA with the trial type as a repeated measure. Unlike the previous experiments (Experiments 10-13), while there was a significant main effect of trial type, $F(1, 38) = 187.8, p < 0.001$, partial Eta-Squared= 0.84, there was no main effect of Condition, $F(1, 38) = 0.182, p = 0.672$, partial Eta-Squared= 0.005.

Overall, the analyses indicated that there were no effects for tone patterns. Thus, it does not appear that the sound effects in Experiments 10-13 stem from young children's inability to ignore task irrelevant information.

These results provide further support the attentional account of label salience, since the tone patterns have a lower familiarity rating as compared to the unfamiliar animals,

and as previously demonstrated, the relative familiarity of stimuli presented in sets dictates what is encoded (more familiar stimuli overshadow less familiar stimuli).

SUMMARY

The experiments presented in this third phase of research were conducted to determine if, in a categorization task, the effects of sounds are best explained by a linguistic proposal (i.e., the semantic or phonetic hypothesis) or the attentional proposal. Experiment 10 established the effects of nonsense count nouns. These results suggest that when pictures are accompanied by nonsense count nouns, young children are less likely to use perceptual similarity to categorize the pictures. Experiments 11-12 substituted vowel patterns that do not resemble English labels for the count nouns and established that effects do not differ from count nouns and that these effects can not be attributed to the referential framework. These results suggest that the effects of labels in categorization do not stem from any assumption that young children have about count nouns denoting category membership. Experiments 13 substituted familiar machine sounds for the count nouns and established that these sounds also produce the same kind of effects as the count nouns. These results suggest that linguistic features make no contribution beyond the contribution made by attentional factors. Finally, Experiment 14 substituted unfamiliar tone patterns for count nouns and demonstrated that not just any sound can produce these effects, as there were no observed effects for the tone-patterns.

However, clearly the findings presented in Chapter 4 differ markedly from the modality dominance effects established in Chapters 2 and 3. Whereas the immediate

recognition paradigm (Experiments 1-8) established that the more familiar sounds were capable of overshadowing visual input, the effects of sounds established in the categorization task (Experiments 10-13) were much smaller and did not overshadow visual input. To explain this difference, it is important to highlight a key difference between the presentation of stimuli between the immediate recognition and categorization task. In the immediate recognition task visual and auditory input were always synchronous, such that the visual stimulus of a set only appeared with its corresponding auditory stimulus, and the different sets were presented sequentially (the first auditory-visual compound was presented for 1000 ms and then followed by a second auditory-visual compound 500 ms later). Alternatively, in the categorization task auditory and visual input were presented in an asynchronous fashion, such that all the visual information was present throughout the trial, and the presentation of auditory information was sequential. This latter paradigm clearly gives the visual modality an advantage, as visual information can be attended to at any time during the trial, since it is available throughout the trial. To verify that this difference in presentation is what produced the difference in effects, a synchronous version of the same categorization task was piloted. The presentation of stimuli differed in that the visual presentation matched the auditory presentation, such that visual stimuli were “hidden” (covered by white circles on the screen) and were only visible while the auditory component was presented. Preliminary data suggest that the effects for familiar machine sounds (i.e., the sounds presented in Experiment 13) are what would be expected if the familiar machine sounds were overshadowing unfamiliar animal pictures (whereas like Experiment 14, there were no effects for 3-tones-patterns). Thus, it appears that limited processing of visual input is

necessary to produce auditory overshadowing. However, demonstrating an effect of sound in categorization does indicate that even when the processing of visual is not limited, visual processing attenuates to a smaller extent, and therefore attentional factors give auditory stimuli a boost.

In general, the finding that familiar machine sounds (Experiment 13) and unfamiliar vowel patterns (Experiments 11-12) are capable of affecting young children's categorical judgments, corroborate with the findings that certain classes of auditory stimuli receive processing priority over certain classes of visual stimuli. Overall results support the attentional account that suggests that some effects of words stem from low-level attentional mechanisms, rather than from participants' understanding of the importance of words for categorization and induction.

CHAPTER 5

GENERAL DISCUSSION

The findings presented in Chapters 2-4 point to several important regularities in the processing of arbitrarily paired auditory-visual input. The results reported in Chapter 2 replicate and further extend results reported by Sloutsky and Napolitano (2003) and Napolitano and Sloutsky (2003). First, this research demonstrates the basic phenomena of modality dominance: when auditory and visual stimuli are presented simultaneously, young children tend to process stimuli presented in one modality, while failing to process the other modality. Second, in young children, modality dominance shifts flexibly: under some conditions particular visual stimuli overshadow particular corresponding sounds, whereas under other conditions these same visual stimuli are overshadowed by different sounds. Third, young children exhibit a default auditory dominance: when both auditory and visual stimuli are unfamiliar, young children tend to process auditory stimuli, while failing to process visual stimuli. Fourth, modality dominance is moderated by stimulus familiarity: young children process more familiar stimuli, while failing to process less familiar stimuli.

The results reported in Chapter 3 reveal the flexible nature of modality dominance. First, this research points to an important asymmetry between visual and auditory

dominance: while visual dominance attenuates or disappears under a variety of attentional manipulations, auditory dominance remains strong, thus indicating that auditory dominance is more robust than visual dominance. The fact that auditory dominance is more robust than visual dominance suggests (in conjunction with earlier findings) that auditory dominance is a developmental default, whereas visual dominance is a product of learning and development. Second, this research indicates that modality dominance effects stem from automatic pulls on attention: even when instructed on every trial to ignore the dominant modality young children cannot completely ignore the dominant modality.

The findings in Chapter 4 are an important first step towards implicating modality dominance as contributing to label salience in young children's conceptual development. First, this research established that young children's use of sounds on a categorization task likely does not stem from any assumptions the children have about count nouns and their role in categorization: the effects produced by both unfamiliar speech strings that do not resemble English nouns and familiar machine sounds followed the same pattern as those produced by sounds that did resemble English count nouns. These findings suggest that low level attentional factors, rather than language specific factors, are responsible for the effects of labels. Second, this research indicates that referential context is not a necessary condition for using auditory input in categorization: presenting the sounds as the animal names or as sounds that the animals like to hear produced the same pattern of effects. Finally, this research established that the effects of auditory input are not caused by a general distraction from visual input by sounds, as there was no effect of sounds

when sounds were unfamiliar tone patterns. These findings suggest that there is no effect of sound when sounds that do not overshadow visual input are used.

Overall, the sum of these results have important theoretical implications, as they affect our understanding of (1) the development of cross-modal processing, (2) the underlying mechanism for modality dominance, and (3) the role of modality dominance in conceptual development.

The Development of Cross-Modal Processing

This research examined how young children process simultaneously presented auditory and visual information under conditions when cross-modal information consists of arbitrary auditory-visual pairings. The results corroborate previous research demonstrating that these conditions result in cross-modal interference effects, with participants failing to process both components of cross-modal stimuli, even though they ably process each component when presented unimodally. Recall that research has demonstrated different modality dominance effects observed at different points in development, with infants exhibiting mostly auditory overshadowing (Robinson & Sloutsky, 2004), young children, exhibiting evidence of both auditory and visual overshadowing (Napolitano & Sloutsky, 2004; Robinson & Sloutsky, 2004; Sloutsky & Napolitano, 2003), and adults exhibiting mostly visual overshadowing (Colavita, 1974; Colavita & Weisberg, 1979). While the presented research did not examine how modality dominance effects vary at different stages of development, it does provide insight into this development.

Chapter 2 demonstrated that for young children transient auditory or highly familiar input, which it has been argued automatically engage attention (Turatto, et al, 2002; Christie & Klein, 1995), are capable of overshadowing the input they correspond with. These findings provide suggestive evidence for automatic attention, as it is the input which is most likely to automatically engage attention that is most likely to be processed. Furthermore, the results provide suggestive evidence that in early childhood when attentional resources are more limited than later in development, these limits in attention do not allow for the processing of multiple sources of input in short periods of time, and thus give way to overshadowing effects.

Chapter 3 (Experiments 6-8) demonstrated that auditory dominance is more robust than visual dominance. This asymmetry suggests that auditory dominance is a developmental default. Recall that Robinson and Sloutsky (2004) demonstrated that auditory dominance tends to decrease with age. At the same time, Sloutsky & Napolitano (2003) found that when neither auditory nor visual stimuli are familiar, participants exhibit auditory dominance, whereas Napolitano and Sloutsky's (2003) findings, in conjunction with the findings presented in Chapter 2, established that visual dominance is limited to situations where familiar visual stimuli are paired with less familiar (or unfamiliar) sounds. Because familiarity is a function of learning, these findings suggest that visual dominance is a function of learning. The idea that auditory dominance is a developmental default, whereas visual dominance is a function of learning is consistent with Posner, et al.'s (1976) hypothesis that the auditory modality automatically summons attention, whereas attending to visual information (of comparable salience) is a product of attentional learning (see also Patching & Quinlan, 2002; Vroomen & de Gelder, 2000,

for similar arguments). The idea that auditory dominance is a developmental default is further supported by results of Experiment 8. These results clearly indicate that visual dominance is more available for deliberate control (i.e., participants were capable of ignoring visual information when instructed to do so) than auditory dominance (i.e., participants were unable to ignore auditory information when instructed to do so). However, more research is needed to further examine this possibility.

Furthermore, the results of Experiment 9 provide important evidence about the development of deliberate attention. Recall that with instructions presented on every trial to ignore the dominant modality, participants did follow instructions, but that processing of a non-dominant modality was significantly lower than processing of this modality in a unimodal baseline. These findings further suggest that early in development, the dominant modality automatically engages attention and participants cannot fully ignore the dominant modality. These findings also point to important limitations of deliberate attention early in development: even when instructions to ignore the dominant modality are presented on every trial, young children cannot completely disengage their attention from the dominant modality. In contrast to young children, adults (as shown in Experiment 8) can follow instructions and focus on one modality while completely ignoring the other modality. Since young children cannot completely ignore the dominant modality even when instructed on every trial, it seems unlikely that they spontaneously ignore the dominant modality. Although this conclusion seems somewhat trivial, it may have non-trivial broader implications for understanding of the role of auditory information in the variety of cognitive tasks (e.g., categorization) and these implications are considered below.

If attentional differences between early childhood and adulthood explain modality dominance effects, then systematic manipulations to either decrease the attentional demands for young children or increase the demands for adults could provide an important link between what happens in early childhood and adulthood. This should be the focus of future research.

While this research only considers arbitrarily paired auditory-visual input, under other conditions cross-modal information includes the same amodal relation expressed both visually and auditorily (e.g., temporal synchrony, rhythm, or tempo), and research has demonstrated that under these conditions even young infants efficiently process information in both modalities (Bahrick, 1988, 2001, 2002; Kuhl & Meltzoff, 1982; Slater, Quinn, Brown, & Hayes, 1999; see also Lewkowicz, 2000a; Lickliter & Bahrick, 2000, for extensive reviews). Furthermore, the research suggests that many amodal relations are more likely to be processed when presented bi-modally than when presented unimodally (see Lewkowicz, 2000a; Lickliter & Bahrick, 2000, for extensive reviews). Thus, cross-modal presentation of amodal relations is likely to result in cross-modal facilitation effects.

Why do children efficiently process both modalities when there is an amodal relation, while exhibiting modality dominance when there are arbitrary relations? There are several plausible explanations. First, the efficient processing of amodal relations may stem from “intersensory redundancy” created by an amodal relation. This redundancy may recruit attention facilitating the efficient processing of both modalities (Bahrick & Lickliter, 2000). It is also possible that some amodal relations used in research on cross-modal processing represent a special case of temporal processing, and there is evidence

that temporal relations might be underlined by a single processing system (see Pashler, 1998). Another possibility (which does not exclude the former two possibilities) is that the divergence stems from the significantly longer stimulus presentation in research on processing of cross-modal relations than that used in the current research (Chapters 2 and 3). If it is hypothesized that the auditory modality habituates faster than the visual modality, then this presentation time difference may play a critical role, since a longer presentation may wash out auditory dominance effects: participants may habituate faster to auditory stimuli, and this asynchronous habituation may enable them to process corresponding visual stimuli. This conflict in findings between studies with amodal and arbitrary presentation should be the focus of future research.

The Underlying Mechanism of Modality Dominance

This research also provides insight into what may be the mechanism underlying modality dominance. Recall the proposition that in the course of cross-modal processing, the two modalities race for attention (cf. Logan's ITAM model, 2002), and whichever modality wins the race takes over processing, thus effectively overshadowing (or attenuating processing of) the other modality. Because the attentional system functions to optimize processing, stimuli that are transient (e.g., auditory stimuli) or highly relevant (e.g., familiar) are processed first, to insure that these inputs are not missed. If this proposition is correct, then in early childhood when attentional resources are limited and the ability to deliberately control attention is questionable, the following outcomes would be expected in a cross-modal task with limited stimulus exposure time: (1) whichever input is more likely to engage attention, should be capable of

overshadowing corresponding input, (2) since visual dominance (which stems from familiarity) has to be the result of learning, it should be easier to experimentally manipulate as compared to auditory dominance which serves as the developmental default, and (3) deliberately shifting attention to nondominant input should be difficult (especially when the dominant input is auditory) since modality dominance effects stem from automatic pulls on attention. These outcomes were the products of Chapters 2 and 3. Specifically, Chapter 2 demonstrated that auditory stimuli overshadow visual stimuli, and that this auditory overshadowing is mediated by familiarity: when visual stimuli are more familiar than auditory stimuli, auditory overshadowing is reversed, and visual stimuli overshadow auditory stimuli. Chapter 3 demonstrated an asymmetry in the nature of auditory and visual overshadowing: auditory dominance is more robust than visual dominance and auditory dominance has greater effect on subsequent visual dominance than the reverse. Chapter 3 also indicated that modality dominance effects are difficult to manipulate: children have trouble ignoring dominant input, especially when it is auditory. However, while this research provides suggestive evidence for the mechanism of modality dominance, systematic manipulations are needed to determine the thresholds for presentation time to produce modality dominance at different points in development, to fully determine if limits in attention in instances of short stimulus presentation are responsible for the overshadowing effects. In other words, longer presentation times in which young children have ample time to process both types of input should wipe out overshadowing effects, but it is unclear just how long presentation needs to be. This issue should be the focus of future research.

Why would a mechanism that processes auditory input before visual input be functional? A general auditory bias early in development could be very adaptive in a world where auditory events are dynamic and transient, whereas visual objects and scenes are usually stable. In particular, visual processing is largely parallel, whereas auditory processing is largely serial. Therefore, auditory dominance may play an important role in the ability of infants and young children to encode novel words: it might be difficult to attend to these transient auditory stimuli in the absence of the auditory dominance.

If novel auditory stimuli overshadow novel visual stimuli, and more familiar stimuli overshadow less familiar stimuli, how do children map novel words onto novel entities? If both auditory and familiarity factors attract attention only to the word, but not to the novel entity the word denotes, such mappings should be impossible. Yet young children often easily map words onto objects (e.g., Carey & Bartlett, 1978; Markson & Bloom, 1997; see Woodward & Markman, 1998, for a review). The key to resolving this apparent contradiction may be that such mappings occurred when objects were either presented for a longer period of time or were presented repeatedly. It seems that both presentation conditions may increase the probability of encoding of visual stimulus. However, additional research is necessary to directly address the issue of interrelationships between overshadowing and fast mapping.

The Contribution of Modality Dominance to Conceptual Development

The reported findings add to the growing body of evidence suggesting the effects of labels on categorization (and induction) stem from general-attentional factors rather than

language-specific factors (Samuelson & Smith, 1998; Campbell & Namy, 2003; Sloutsky & Napolitano, 2003; Napolitano & Sloutsky, 2003; Robinson & Sloutsky, 2004).

Previous research has demonstrated that when two entities share a label, young children will often ignore perceptual similarity, and categorize based on shared label (e.g., Markman & Hutchinson, 1984). While it is reasonable to speculate that young children have an assumption that labels convey category membership (Gelman & Coley, 1991), it does not appear that young children fully deploy this knowledge in the categorization task presented in Chapter 4: the effects of count nouns did not differ from the effects of other classes of familiar input. Thus, the demonstrated effects of sound appear to be better explained by attentional factors rather than semantic factors. These findings clearly contradict any explanation for label salience which proposes that children rely on domain specific knowledge in this kind of task. Furthermore, the findings support the proposed attentional account for label salience in cognition, which argues that effects of labels stem from labels engaging attention first and thus partially overshadowing corresponding the input that is subsequently processed.

It is unclear the extent that the attentional features of auditory and visual input can explain previous findings in other lines of research on conceptual development. While some of the previous research has considered the role of sound alone (Waxman & Markow, 1995; Balaban & Waxman, 1997; Roberts & Jacob, 1991), the relative familiarity of stimuli has been often ignored, and the current results clearly demonstrate that the familiarity of stimuli is a powerful mediating factor in what input is processed. Furthermore, familiarity of information could be important for other types of input as well. For example, Davidson and Gelman (1990) demonstrated that when categorical

information is familiar, children are more likely to rely on this information over perceptual features to determine whether the entities are members of the same natural kind category. Also, while the presented results suggest that the familiarity of the source of the sounds affects the attentional weight of the sound, it remains unclear whether using highly familiar labels would contribute to the attentional weights of the sounds even further. There is some indirect evidence suggesting it might. Specifically, it has been demonstrated that children judged inferences made from highly typical animals (e.g., dog) to all other animals stronger than they judged inferences made from less typical animals (e.g., bat) to all other animals (Lopez, Gelman, Guthrie, & Smith, 1992). While Lopez et al. (1992) argued that these findings indicate that young children's induction could be affected by typicality of information, it is possible that results may actually stem from the higher familiarity of the labels (i.e., the label dog is more familiar than bat) of the typical animals (see, Fisher & Sloutsky, 2005, for a detailed account of this interpretation). Future research is needed to further explore the role of low level attentional features that may not only drive label salience, but may also drive the effects of other input that affect conceptual development.

Overall, these findings indicate that modality dominance effects do indeed have important implications for research on young children's conceptual development. However, this was only the first step in directly examining their role in conceptual development, and more research is needed.

Conclusion

Results of experiments reported in Chapters 2-4 indicate that in auditory-visual cross-modal processing: (1) modality dominance effects can be attributed to the one input's

ability automatically engage attention relative to another input: young children tend to process stimuli that are auditory or familiar over stimuli that are visual or unfamiliar, (2) auditory dominance is the developmental default, whereas visual dominance is dependant on familiarity and learned: attentional manipulations can decrease or wipe-out visual but not auditory dominance, (3) modality dominance effects stem from automatic pulls on attention: young children cannot completely ignore the dominant modality even when instructed to do so on every trial, and (4) young children's use of labels in categorization tasks may be better explained by labels' attentional features than conceptual knowledge: both nonsense count nouns and familiar nonlinguistic sounds had the same effect on young children's categorization. These results support the attentional account of modality dominance and its possible role in label salience, and present a challenge to linguistic accounts of label salience. However, although the sum of the reported research does provide consistent and compelling support for the attentional account, several questions remain, and finding answers to these questions should be the focus of future research.

BIBLIOGRAPHY

- Aslin, R., Pisoni, D. B., & Jusczyk, P. W. (1983). Auditory perception and speech development in early infancy. In M. Haith & J. Campos (Eds.), *Handbook of child psychology: Vol. 2. Infancy and developmental psychobiology* (pp. 573-687). New York, NY: Wiley.
- Aslin, R., & Smith, L. (1988). Perceptual development. *Annual Review of Psychology*, 39, 435-474.
- Balaban, M. T., & Waxman, S.R. (1997). Do words facilitate object categorization in 9-month-old infants? *Journal of Experimental Child Psychology*, 64, 3-26.
- Bahrnick, L. E. (2002). Generalization of learning in three-and-a-half-month-old infants on the basis of amodal relations. *Child Development*, 73, 667-681.
- Bahrnick, L. E. (2001). Increasing specificity in perceptual development: Infants' detection of nested levels of multimodal stimulation. *Journal of Experimental Child Psychology*, 79, 253-270.
- Bahrnick, L. E. (1988). Intermodal learning in infancy: Learning on the basis of two kinds of invariant relations in audible and visible events. *Child Development*, 59, 197-209.
- Bahrnick, L. E., & Lickliter, R. (2000). Intersensory redundancy guides attentional selectivity and perceptual learning in infancy. *Developmental Psychology*, 36, 190-201.
- Baldwin, D., & Markman, E. (1989). Establishing word-object relations: A first step. *Child Development*, 60, 381-389.
- Ballas, J. A. (1993). Common factors in the identification of an assortment of brief everyday sounds. *Journal of Experimental Psychology: Human Perception & Performance*, 19, 250-267.
- Banks, M. S., & Salapatek, P. (1983). Infant visual perception. In P.H. Mussen (Series Ed.), *Handbook of child psychology: Vol. 2. Infancy and developmental psychobiology* (pp. 435-571). New York, NY: Wiley.

- Birnholz, J. C., & Benaceraff, B. B. (1983). The development of human fetal hearing. *Science*, 222, 516-518.
- Campbell, A. L., & Namy, L. L. (2003). The role of social-referential context in verbal and nonverbal learning. *Child Development*, 74, 549-563.
- Carey, S., & Bartlett, E. (1978). Acquiring a single new word. *Papers and Reports on Child Language Development*, 15, 17-29.
- Christie, J., & Klein, R. (1995). Familiarity and attention: Does what we know affect what we notice? *Memory & Cognition*, 23, 547-550.
- Colavita, F. B. (1974). Human sensory dominance. *Perception & Psychophysics*, 16, 409-412.
- Colavita, F. B., & Weisberg, D. (1979). A further investigation of visual dominance. *Perception & Psychophysics*, 25, 345-347.
- Cooper, R. P., & Aslin, R. N. (1990). Preference for infant directed speech in the first month after birth. *Child Development*, 61, 1584-1595.
- Cycowicz, Y. M., & Friedman, D. (1998). Effect of sound familiarity on the event-related potentials elicited by novel environmental sounds. *Brain & Cognition*, 36, 30-51.
- Davidson, N. S., & Gelman, S. A. (1990). Inductions from novel categories: The role of language and conceptual structure. *Cognitive Development*, 5, 151-176.
- Egeth, H. E., & Sager, L. C., (1977). On the locus of visual dominance. *Perception & Psychophysics*, 22, 77-86.
- Egeth, H. E., & Yantis, S. (1997). Visual attention: Control, representation, and time course. *Annual Review of Psychology*, 48, 269-297.
- Eimas, P. D., Siqueland, E. R., Jusczyck, P., & Vigorito, J. (1971). Speech perception in infants. *Science*, 171, 303-306.
- Fenson, L., Dale, P. S., Reznick, J. S., Bates, E., Thal, D. J., & Pethick, S. J. (1994). Variability in early communicative development. *Monographs of the Society for Research in Child Development*, 59, (No. 4, Serial No. 242).
- Fernald, A. (1992). Human maternal vocalizations to infants as biologically relevant signals: An evolutionary perspective. In J.H. Barlow, L. Cosmides, & J. Tooby (Eds.), *The adapted mind* (pp 391-428). Oxford: Oxford University Press.

- Fernald, A., & Simon, T. (1984). Expanded intonation contours in mothers' speech to newborns. *Developmental Psychology*, 20, 104-113.
- Fisher, A. V., & Sloutsky, V. M. (2005). When induction meets memory: Evidence for gradual transition from similarity-based to category-based induction. *Child Development*, 76, 583-597.
- Gelman, S. A., & Coley J. (1991). Language and categorization: The acquisition of natural kind terms. In S.A. Gelman, & J.P. Byrnes (Eds.). *Perspectives on language and thought: Interrelations in development* (146-196). New York: Cambridge University Press.
- Gelman, S. A., & Heyman, G. D. (1999). Carrot-eaters and creature-believers: The effects of lexicalization on children's inferences about social categories. *Psychological Science*, 10, 489-493.
- Gelman, S. A., & Markman, E. (1986). Categories and induction in young children. *Cognition*, 23, 183-209.
- Hölscher, C., Rolls, E. T., & Xiang, J.-Z. (2003). Perirhinal cortex neuronal activity related to long-term familiarity memory in the macaque. *European Journal of Neuroscience*, 18, 2037-2046.
- Jones, S. S., & Smith, L. B. (2002). How children know the relevant properties for generalizing object names. *Developmental Science*, 5, 219-232.
- Jones, S. S., Smith, L. B., & Landau, B. (1991). Object properties and knowledge in early lexical learning. *Child Development*, 62, 499-516.
- Jusczyk, P. W. (1998). *The discovery of spoken language*. Cambridge, MA: MIT Press.
- Jusczyk, P., & Bertoncini, J. (1988). viewing the development of speech perception as an innately guided learning process. *Language and Speech*, 31, 217-238.
- Jusczyk, P., Pisoni, D.B., Reed, M. A., Fernald, A., & Myers, M. (1983). Infants' discrimination of the duration of a rapid spectrum change in nonspeech signals. *Science*, 222, 175-176.
- Kirkham, N. Z., Cruess, L., & Diamond, A. (2003). Helping children apply their knowledge to their behavior on a dimension-switching task. *Developmental Science*, 6, 449-476.
- Kuhl, P. K., & Meltzoff, A. N. (1982). The bimodal perception of speech in infancy. *Science*, 218, 1138-1141.

- Lamberts, K. (1994). Flexible tuning of similarity in exemplar-based categorization. *Journal of Experimental Psychology: Learning, Memory, & Cognition*, 20, 1003-1021.
- Lewkowicz, D. J. (2000a). The development of intersensory temporal perception: An epigenetic systems/limitations view. *Psychological Bulletin*, 126, 281-308.
- Lewkowicz, D. J. (2000b). Infants' perception of the audible, visible, and bimodal attributes of multimodal syllables. *Child Development*, 71, 1241-1257.
- Lewkowicz, D. J. (1994). The development of intersensory perception in human infants. In D. J. Lewkowicz, & R. Lickliter (Eds.). *The Development of perception: Comparative perspectives* (165-203). Hillsdale: Lawrence Erlbaum Associates, Inc.
- Lewkowicz, D. J. (1988a). Sensory dominance in infants: 1. Six-month-old infants' response to auditory-visual compounds. *Developmental Psychology*, 24, 155-171.
- Lewkowicz, D. J. (1988b). Sensory dominance in infants: 2. Ten-month-old infants' response to auditory-visual compounds. *Developmental Psychology*, 24, 172-182.
- Lickliter, R., & Bahrick, L. E. (2000). The development of infant intersensory perception: Advantages of a comparative convergent-operations approach. *Psychological Bulletin*, 126, 260-280.
- Logan, G. D. (2002). An instance theory of attention and memory. *Psychological Review*, 109, 376-400.
- Lopez, A., Gelman, S., Guthrie, G., & Smith, E. E. (1992). The development of category-based induction. *Child Development*, 63, 1070-1090.
- Mehler, J., Jusczyk, P. W., Lambertz, G., Halsted, N., Bertoni, J., & Amiel-Tison, C. (1988). A precursor to language acquisition in young infants. *Cognition*, 29, 143-178.
- Markman, E. M. (1989). *Categorization and naming in children: Problems of induction*. Cambridge, MA: MIT Press.
- Markman, E. M., & Hutchinson, J. E. (1984). Children's sensitivity to constraints on word meaning: Taxonomic versus thematic relations. *Cognitive Psychology*, 16, 1-27.
- Markman, E. & Wachtel, G. F. (1988). Children's use of mutual exclusivity to constrain the meaning of words. *Cognitive Psychology*, 20, 121-157.
- Markson, L., & Bloom, P. (1997). Evidence against a dedicated system for word learning in children. *Nature*, 385, 813-815.

- Meltzoff, A. N., & Borton, R. W. (1979). Intermodal matching by human neonates. *Nature*, 282, 403-404.
- Merriman, W. E., & Schuster, J. M. (1991). Young children's disambiguation of object name reference. *Child Development*, 62, 1288 – 1301.
- Napolitano, A. C., & Sloutsky, V. M. (2003). Flexible attention and modality preference in young children. In R. Alterman & D. Kirsh (Eds.), *Proceedings of the XXV Annual Conference of the Cognitive Science Society* (pp. 846-850). Mahwah, NJ: Erlbaum.
- Nosofsky, R. M. (1986). Attention, similarity, and the identification-categorization relationship. *Journal of Experimental Psychology: General*, 115, 39-57.
- Pashler, H. E. (1998). *The psychology of attention*. Cambridge, MA: MIT Press.
- Pashler, H., Johnston, J. C., & Ruthruff, E. (2000). Attention and performance. *Annual Review of Psychology*, 52, 629-651.
- Patching, G. R., & Quinlan, P. T. (2002). Garner and congruence effects in the speeded classification of bimodal signals. *Human Perception and Performance*, 28, 755-775.
- Posner, M. I., Nissen, M. J., & Klein, R. M. (1976). Visual dominance: An information-processing account of its origins and significance. *Psychological Review*, 83, 157-171.
- Roberts, K (1995). Categorical responding in 15-month-olds: Influence of the noun-category bias and the covariation between visual fixation and auditory input. *Cognitive Development*, 10, 21-41.
- Roberts, K., & Jacob, M. (1991). Linguistic versus attentional influences on nonlinguistic categorization in 15-month-old infants. *Cognitive Development*, 6, 355-375.
- Robinson, C. W., & Sloutsky, V. M. (2004). Auditory dominance and its change in the course of development. *Child Development*, 75, 1387-1401.
- Samuelson, L. K., & Smith, L. B. (1998). Memory and attention make smart word learning: An alternative account of Akhtar, Carpenter, and Tomasello. *Child Development*, 69, 94-104.
- Scholl, B. J., Pylyshyn, Z. W., & Feldman, J. (2001). What is a visual object? Evidence from target merging in multiple object tracking. *Cognition*, 80, 159-177.
- Slater, A., Quinn, P. C., Brown, E., & Hayes, R. (1999). Intermodal perception at birth: Intersensory redundancy guides newborn infants' learning of arbitrary auditory-visual pairings. *Developmental Science*, 2, 333-338.

- Sloutsky, V. M., & Fisher, A. V. (2004). Induction and categorization in young children: A similarity-based model. *Journal of Experimental Psychology: General*, 133, 166-188.
- Sloutsky, V. M., & Lo, Y. (1999). How much does a shared name make things similar? Part 1: Linguistic labels and the development of similarity judgment. *Developmental Psychology*, 6, 1478-1492.
- Sloutsky, V. M., & Napolitano, A. C. (2003). Is a picture worth a thousand words? Preference for auditory modality in young children. *Child Development*, 74, 822-833.
- Smith, L. B., Jones, S. S., & Landau, B. (1996). Naming in young children: A dumb attentional mechanism. *Cognition*, 60, 143-171.
- Turatto, M., Benso, F., Galfano, G., & Umiltà, C. (2002). Nonspatial attentional shifts between audition and vision. *Journal of Experimental Psychology: Human Perception and Performance*, 28, 628-639.
- Vroomen, J., & de Gelder, B. (2000). Sound enhances visual perception: Cross-modal effects of auditory organization on vision. *Journal of Experimental Psychology: Human Perception and Performance*, 26, 1583-1590.
- Waxman, S. R., & Markow, D. B. (1995). Words as invitations to form categories: Evidence from 12- to 13-month-old infants. *Cognitive Psychology*, 29, 557-302.
- Welder, A. N., & Graham, S. A. (2001). The influences of shape similarity and shared labels on infants' inductive inferences about nonobvious object properties. *Child Development*, 72, 1653-1673.
- Werker, J.F., Cohen, L.B., Lloyd, V.L., Casasola, M., & Stager, C.L. (1998). Acquisition of word-object associations by 14-month-old infants. *Developmental Psychology*, 34, 1289-1309.
- Woodward, A. L., & Markman, E. M. (1998). Early word learning. In D. Kuhn & R. Siegler (Eds.), W. Damon (Series Ed.), *Handbook of child psychology: Vol 2. Cognition, perception, and language* (5th ed., 371-420), New York: Wiley.
- Xiang, J.-Z., & Brown, M. W. (1998). Differential neuronal encoding of novelty, familiarity, and recency in regions of the anterior temporal lobe. *Neuropharmacology*, 37, 657-676.
- Zelazo, P. D., Frye, D., & Rapus, T. (1996). An age-related dissociation between knowing rules and using them. *Cognitive Development*, 11, 37-63.