SHAKING THINGS UP: YOUNG INFANTS' USE OF SOUND INFORMATION FOR

OBJECT INDIVIDUATION

A Thesis

by

TRACY REBECCA SMITH

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

December 2007

Major Subject: Psychology

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Approved by:

Chair of Committee,	Teresa G. Wilcox
Committee Members,	Gerianne Alexander
	Carl Gabbard
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ABSTRACT

Shaking Things Up: Young Infants' Use of Sound Information for Object Individuation.

(December 2007)

Tracy Rebecca Smith, B.S., Texas A&M University

Chair of Advisory Committee: Dr. Teresa G. Wilcox

Object individuation, the capacity to determine whether two perceptual encounters belong to the same object or two different objects, is one of the most basic cognitive abilities and provides a foundation for infants' understanding of the physical world. Yet very little work has been done to explore infants' use of auditory information to individuate objects. The first research to investigate infants' use of sound information to individuate objects was reported by Wilcox et al. (2006), who used a violation-of-expectation task to examine the extent to which 4.5-month-olds use differences in sound to individuate objects. The results suggested that 4.5-month-olds use property-rich sounds (sounds intimately related to an objects' physical, amodal properties) but not property-poor sounds (sounds that are more contrived) to distinguish the identity of objects involved in occlusion events.

The current study investigated infants' sensitivity to these two types of sounds within the context of a search task. Three experiments were conducted with infants aged 5 to 7 months. The outcome of these experiments builds and extends on the findings of Wilcox et al. in three ways. First, converging evidence was obtained, using a search task,

that young infants are more sensitive to property-rich than property-poor sounds. Second, more detailed information was obtained on infants' interpretation of same-sounds events (two identical, rather than two different, sounds). Finally, possible explanations for infants' greater sensitivity to property-rich sounds were assessed. The outcome of these studies, collectively, provides insight into the types of sounds that infants use to identify objects and the reasons why some sounds are more salient to infants than others.

DEDICATION

       This Master's Thesis is dedicated in three parts. Experiment 1 is dedicated to Jesus Christ, my Lord and Savior, who has richly blessed me with this opportunity to study developmental psychology at Texas A&M with the most precious and amazing graduate advisor, fellow graduate students, and funding! Experiment 2 is dedicated to two particular groups of babies: first, the infants who participated in this experiment and made me a little crazy with their antics in response to property-poor sounds, and second, the babies who have inspired me over the years with their precious souls, particularly my baby brother and baby sister. Experiment 3 is dedicated to my parents, whose words have always matched their actions. Their love, support, and living examples provided me with the confidence to reach this stage of education and the grounding to survive it.

ACKNOWLEDGEMENTS

I would like to thank my committee chair, Dr. Wilcox, and my committee members, Dr. Gabbard and Dr. Alexander, for their helpful guidance, enthusiasm, and patience throughout the course of this research.

Thanks and love also go to my friends and colleagues in the Infant Cognition Lab, particularly Dr. Rebecca Woods and Jennifer Armstrong. I, also, have a special place of overwhelming gratitude in my heart for the Aggies who helped collect and code data: Jennifer Moore, Veronica Gonzales, Kayla Boone, Rachel Fenner, Monica Garza, to name a few. Furthermore, this research project would not have been possible without the much-appreciated support and generosity from the families of Bryan/College Station, who were willing to participate in the study.

A special shout-out belongs to all the friends who supported me by keeping me on-task at Blue Baker or other favorite study spots, particularly Didi Martinez, Maria San Andres, Faith Payne, and Brittany Bruton. Thanks, also, to the special friends who gave me a break: Jessica Jones (bff), Princess Lacie, Lacy Ledford, Alisha Lombardi, Valerie Blakey, and my beloved sister, Hannah Smith.

Finally, thanks to God, "who takes hold of [my] right hand, and says to [me], 'Do not fear; I will help you'" (Isaiah 41:13), without whom nothing would be possible. I offer indescribable gratitude to my fun parents, who gave me wisdom, encouragement, editing, and more love than any daughter could deserve. "Train up a child in the way [she] should go, and when [she] is old [she] will not depart from it" (Proverbs 22:6).

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1. INTRODUCTION: OBJECT INDIVIDUATION USING SOUND

When pondering infants' use of auditory information, an observation of Johann Wolfgang von Goethe seems appropriate: "If children grew up according to early indications, we should have nothing but geniuses" (Mohler, 1994, Johann Wolfgang von Goethe section, para. 1). Infants use experience with, and knowledge about, auditory cues in a vast number of ways, including those for the purpose of interpreting physical events and learning about the physical world. Prior to birth, babies detect and respond to familiar sounds in the womb and demonstrate sensitivity to differences in pitch, loudness, and timbre early in the first year (Aslin, Jusczyk, & Pisoni, 1998). Infants as young as 4.5 months recognize the visually discernable, physical components of an auditory stimulus (Bahrick, 1983, 1987; Dodd, 1979; Spelke, 1979; LaGasse, et. al., 1999). For example, young infants can identify whether a sound event is produced by a single object, or multiple objects, moving inside a container (Bahrick, 1987) and whether impact sounds are consistent with rigid or compressible objects (Bahrick, 1983). These results suggest that infants are sensitive to the temporal structure and synchrony of multimodal events involving sights and sounds, and they can identify whether the sounds objects produce are consistent with the objects' physical properties. More important to the present research, these results suggest that infants are capable of linking sounds to individual objects, particularly when those sounds are intimately linked to the physical properties of the objects.

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This thesis follows the style of *Infancy.*

Recently, Wilcox and her colleagues (Wilcox, Woods, Tuggy, & Napoli, 2006) investigated the extent to which infants use differences in sound to individuate objects. In these studies, 4.5-month-olds were shown an event in which an object, which started at the left edge of a platform, moved behind the left edge of a wide screen. Once occluded, infants heard two distinct sounds, separated by a short pause, originate from behind the screen. After the sound event, an object identical in appearance emerged from behind the right side of the screen and came to rest at the right edge of the platform. The screen was then lowered to reveal just the one object, sitting at the right edge of the platform or two objects, the one object sitting at the right edge of the platform and a second object behind the lowered screen. Infants were tested in one of two sound conditions: property-rich or property-poor.

Wilcox et al., (2006) define **property-rich sounds** as sounds that are intrinsically tied to an object's physical properties (e.g., a wooden ball hitting a solid surface) and **property-poor sounds** as sounds that are more contrived and ambiguously linked to objects (e.g., the ringing of a telephone or doorbell). In the property-rich condition, the sounds were produced by shaking two rattles filled with different substances (e.g., dried rice or small metal bells). In the property-poor condition, an electronic keyboard was used to produce two tones that differed in pitch and timbre. The infants in the property-rich condition looked reliably longer at the one- than the two-object display, suggesting that they interpreted the sound event as involving two objects and were surprised to see a single object when the screen was lowered. In contrast, the infants in the property-poor condition looked about equally at the two displays, suggesting that they were ambiguous

in their interpretation of the sound event (e.g., they did not know whether the electronic sounds belonged to the same object or two different objects). In unpublished findings, Wilcox and her colleagues found that infants do not begin using the property-poor sounds for object individuation until approximately 11.5 months.

Other researchers have proposed a similar distinction between types of sounds. For example, drawing on the Gibsonian idea of direct perception, Coward and Stevens (2004) consider sounds to be comprised of invariant properties that signify the physical characteristics of objects and how they interact with their environment (Gibson, 1979; Michaels & Carello, 1981). Coward and Stevens (2004) propose that there are two ways in which sounds get mapped onto objects: symbolic mapping and nomic mapping. Although both kinds of mappings must be learned, some types of object-sound associations are more difficult to learn than another others. Nomic associations are those in which sounds and objects are intimately and physically linked, and involves the mapping of sounds to objects during events in which objects and their interactions are physically capable of producing the sound (e.g. hitting sticks on a drum). Nomic associations are obvious and easy for adults to detect. Symbolic associations, on the contrary, involve the mapping of sounds onto objects in situations where the sounds are not obviously and directly related to the objects (i.e., there is no causal relation between the object or its parts and the sound produced). Typically, symbolic mappings are more difficult than nomic mappings and gain meaning only from social convention (i.e., sirens associated with emergency vehicles).

In their investigation of nomic and symbolic mapping in adults, Coward and Stevens (2004) reported that initially, adults found learning nomic associations easier than learning symbolic associations. However, by the end of the learning session adults were able to successfully identify symbolic associations and, in fact, symbolic associations were learned with greater accuracy than nomic associations. Coward and Stevens (2004) suggest that certain aspects of sound are consistent indicators of the physical properties behind it; for example, frequency is an accurate predictor of size, and temporal and spectral components are predictors of quantity and substance. These sound components allow for quick analysis of sound events, and the result is successful nomic mapping in the intial stages of learning. However, with training or experience, adults learn to associate sounds with objects, and once these symbolic mappings are made, they are used with equal or greater accuracy (see Jacko and Rosenthal, 1997 for related results with children). Nomic and symbolic mapping can be likened to the distinction by Wilcox et al. (2006) regarding property-rich sounds and property-poor sounds, respectively.

Other infant researchers have also suggested that object-related sounds can be classified as belonging to one of two broad categories: sounds that clearly arise from an object's physical properties and sounds that we learn to associate with an object. Walker-Andrews (1994) described these two types of sound events as involving natural relations versus artificial relations. Natural relations between objects and sound embody typical or physically-caused relations between objects and sound, and they are common in the natural environment. The deeper, louder sounds from heavy objects hitting the

ground versus lighter objects provides one example; physical properties such as substance and composition directly relate to the sound produced from an object interacting with its own parts or its environment.

Mapping artificial sounds onto objects must be learned by association because they are not so constrained by physical properties or temporal relations such as size or synchrony, e.g. cell phones that can make a variety of noises at any given time) (Walker-Andrews, 1994). The work of Coward and Stevens (2004) and Walker-Andrews (1994) provide converging evidence for the distinction between property-rich and property-poor sounds and for the idea that some types of sounds may be more salient than others, at least under some conditions. The purpose of the present study was to provide converging evidence, using a different behavioral paradigm, that young infants are more sensitive to property-rich than property-poor sounds for object individuation and to explore the underlying basis for this sensitivity.

2. RESEARCH OBJECTIVES

Experiment 1

Experiment 1 assessed 5- to 7-month-olds' ability to use property-rich sounds to individuate objects during a search task. In the initial phase of the task (Figure 2), the experimenter presented infants with an event in which an object was placed on the left edge of a platform, shaken for 2 s during which the object produced a sound, then slid across the platform until it disappeared behind one edge of a fringed-screen, and then an object identical in appearance emerged from behind the other edge of the screen, when it reached the right edge of the platform, it was shaken a second time that coincided with a second sound. In the final phase of the task, the platform was moved forward so that the screen was directly in front of the infant, and the infant was allowed to search. The two sounds were either identical in their auditory components (e.g., sounds produced by the same rattle) or different in their auditory components (e.g., one sound produced by a rattle filled with dried rice and the other filled with jingle bells).

If the infants in the different-sounds condition used the sound difference to signal the presence of two distinct objects, and recognized that one of the objects must be hidden behind the screen at the end of the occlusion sequence, then they should persist at reaching through the fringed-screen. They should spend more time reaching through the fringed-screen than reaching for the ball at the end of the platform. Furthermore, if the infants in the same-sounds condition interpreted the event as involving a single object that comes to rest at the end of the platform, they should spend more time reaching to the visible object than through the screen (since the screen does not hide an object). In contrast, if

the infants in the same-sounds and different-sounds condition failed to use auditory information to draw conclusions about the number of objects involved in the event, they should reach equally to the screen and the visible object.

If the infants interpreted the event as involving two distinct objects (i.e., used the difference in sound to conclude that the objects seen to the left and the right side of the screen constituted two different objects), they should have spent more time searching for the second object behind the screen than reaching for the visible object. If the infants interpreted the different-sounds event as involving only a single object (i.e., failed to use the difference in sound to individuate the objects), they should have spent more time reaching for the visible object than searching behind the screen (since they did not expect a second object to be behind the screen).

Method

Participants

Twenty-six 5- to 7-month-olds were included in the sample, 15 male, 11 female (*M* age=6 months, 22 days; range = 5 months, 20 days to 7 months, 15 days). Seven additional babies tested were not included in the sample because they failed to contribute at least one test trial: six because they failed to engage in the task (i.e., failed to watch the occlusion events or failed to reach) and one because she reached continuously to both the ball and the screen simultaneously. Infants were randomly assigned to one of four conditions formed by crossing event (different or same sounds) and sound (rattle sound or dried rice sound).

Apparatus

The infant sat in parent's lap at a table 122 x 94 cm with a rectangular section 13 x 18 cm cut out of one side, to facilitate infant's reaching (see Figure 1.). The display included an occlusion event performed on a wooden platform 80 x 40 cm with a strip of flannel laying lengthwise down the center to allow for smooth movement of the objects. The occluder was a 30 x 22 cm blue wooden frame with four layers of vertically cut muslin attached. Infants could not see through the screen, which was firmly held into the platform by wooden pegs equidistant from the right and left edges of the platform.

The egg-shaped objects used in the test events were 7.5 cm in diameter at their widest points and 11 cm tall, made of paper-mâché, lined with plastic, hollow, and painted blue. To produce property-rich sounds, two eggs were partially filled with uncooked rice and two with small jingle bells. To equate the conditions as much as possible (see below), two objects were used to produce the different- and same-sounds events. Using a computer program to analyze the sound's frequency, the rice sound presented a high frequency measuring 3000 Hz, and higher during spikes, while the rattle sound measured at a mid-frequency surrounding 3000 Hz.
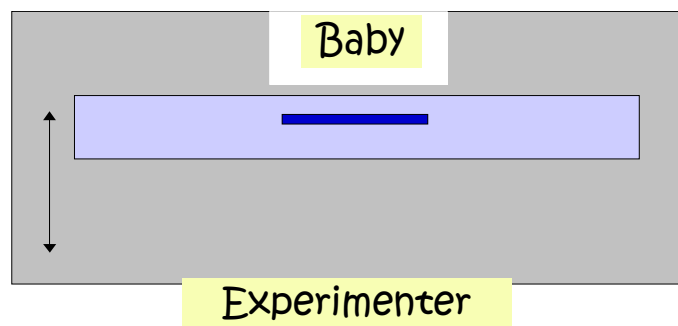

Figure 1.   *Table with Platform.*

Auditory Events and Conditions

    Different sounds. First, experimenter placed the blue, egg-shaped object on far left (infant's point-of-view) end of platform. As soon as infant was looking at the object in its starting position at the far left of the platform (infant's point of view), the experimenter began the event: 2s of shaking the object in an up-and-down motion simultaneously with the appropriate sound (approximately 3 shakes per second at 70db). To produce the sound, the egg was filled with dried rice. Next, the experimenter smoothly slid the object across the platform at an approximate rate of 4cm per second until occluded behind the fringed screen, then an identical object emerged from the other side of the screen until it reached the other end of the platform, where the object was shaken a second time for a second sound (of 2s at 70db). The second egg contained small, jingle bells that rattled when shaken. The entire event was smooth in motion and 12 s in duration. Sound order was counterbalanced, so half of the infants in the different-sounds condition heard dried rice first, and the other half heard the small, jingle bells first, though no order effects were found.

    Same sounds. In the same sounds condition, the event followed exactly the same sequence. To equate the conditions, two objects were used with same-sounds as well, but the infant heard "jingle bells" on both sides of the screen or "dried rice" on both sides of the screen. See Figure 2 for pictorial representation of conditions of test events.

Same Sounds	Shake 2 sec *Dried rice (or Jingle bells)* ... Shake 2 sec *Dried rice (or Jingle bells)*
Different Sounds	Shake 2 sec *Jingle bells (or Dried rice)* ... Shake 2 sec *Dried rice (or Jingle bells)*
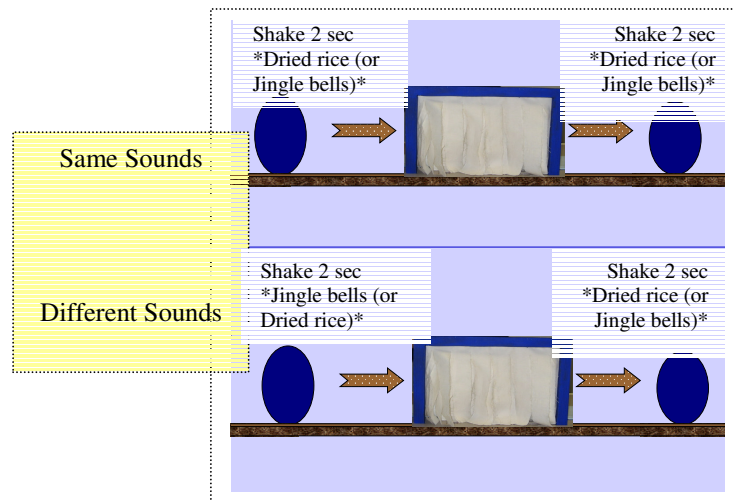
Figure 2.   *Possible Test Conditions for Experiment 1.*

Procedure

The infant sat on a parent's lab centered in front of the table within the square cutout. To normalize infants' relation to the table, the tabletop crossed at the midway point between the infant's seat, resting on the parent's lap, and the top of the infant's shoulder to allow for ease of infant reaching (Choi & Mark, 2004).

Infants were given three familiarization trials designed to acquaint them with the screen and the task. Familiarization trials also established all infants as active reachers. In trial 1, they were encouraged to touch and put their hand through the screen. This was accomplished by the experimenter pushing the platform within the infant's reach, as determined by half the length of the infant's fingers to penetrate the fringed screen, with outstretched arm. This typically meant the platform rested two to three inches from the table's edge in front of the infant. The experimenter then reached toward the baby

through the fringe as well as looked at the baby through the fringe. Once the infant placed his or her hand through the fringed-screen twice, the trial ended.

In the second familiarization trial, infants saw a small toy (a yellow plastic lion) sitting at the left edge of the platform; the lion was rotated, or danced, from side-to-side three times and then moved along the platform until it was fully hidden behind the screen. Next, the screen was pushed forward and infants were allowed to search for 20 s. Because many infants were initially hesitant to search, the experimenter squeaked the lion before starting the event to encourage search behavior. If after 5 seconds the infant failed to attain lion, the experimenter pushed the lion forward to show a bulge in the fringe from the infant's point of view. If another 5 seconds passes without the infant obtaining the lion, the experimenter pulled back half of the fringe so half of the lion was visible to infant. Finally, if another 5 seconds passed without the infant's retrieval of toy lion, the experimenter fully revealed the lion so that there was no fringe in front of it. If the infant still did not grab toy lion, the experimenter handed it to infant, then pulled platform back out of infant's reach. Once the infant retrieved the toy, the trial ended and the platform was pulled back to its starting position. The second trial was identical to the first except that the yellow lion was replaced with a red and blue rattle.

Following the familiarization trials, test trials ensued in which infants viewed an auditory event on the aforementioned platform, according to their appropriate condition (same sounds or different sounds). Sitting at the table, infants could view the auditory event and search when the platform was pushed forward. Once the auditory event was completed, denoted by the object coming to rest at the right edge of the platform, the

platform was then pushed forward and infants were allowed to search. Infants were presented with two test trials that each allowed 20 seconds of search time. Following each trial, the experimenter pulled back the platform to its starting position.

The session was video-taped and later coded using Noldus ObserverPro 5.0. Familiarization trials were coded on the basis of the level of experimenter's help required in order for infant to attain the hidden toy during familiarization trials two and three. After the infant watched the experimenter slide the lion (or rattle) behind the fringed screen, the experimenter followed a script for helping the infant to reach and grab the toy. No help needed was categorized as a level "0." After an initial 5s, experimenter pushed toy toward infant, creating a bulge in the fringe (level 1). After waiting another 5s, the experimenter pulled back half of the fringe, revealing half of the toy, level 2. After another 5s passed, the experimenter pulled back the remaining fringe that covered half of the toy, leaving the toy fully visible, level 3. If the infant failed to grab the object after another 5s, the experimenter reached through and handed the toy to the infant, level 4. Level of help was categorized from 0, no help, to 4, experimenter handing toy to infant, or level 5, denoting that the infant never touched the object. Although the main purpose of the familiarization trials was to acquaint the infants with the search task, coding and analysis of familiarization search data allowed us to assess whether the infants in the two conditions were equitable in the extent to which they were willing or able to engage in the search task and establish both groups as active reachers.

During test trials, several factors of infant behavior were coded. First, infants' failure or success at observing the test event, or occlusion sequence, was coded. Infant

trials were excluded from the analysis if the infant did not see the occlusion of the object, as the experimenter moved it behind the fringed screen, or the emergence, as the experimenter moved the visually identical egg out from behind the screen to the far right edge of the platform (infant point-of-view). Five of the twenty-six infants included in the sample, only contributed only one of two possible trials because they failed to watch the initial phase of the event.

The second phase of the search task, which followed the occlusion sequence, was 20s in duration. This phase began when the experimenter pushed the platform forward to within the infant's reach. Observers, blind to experimental condition, coded for duration of actions directed toward the screen (defined as making contact) and/or the visible object. A reach to the visible object was defined as the infant's arm extended at least half the distance from the front edge of the platform toward the object, with fingers outstretched and pointed in the direction of the object in view. As the screen was within easy reach of the infant, the infant's fingers or hand had to be touching part of the screen or extended through the fringe to be coded as a behavior directed toward the fringed screen. The object in view, however, was positioned slightly out of infant's reach, as designed by McCurry, Wilcox, and Woods (2007) due to concerns that if the object in view was within easy reach, infants would immediately reach for that regardless of whether a second object was hidden behind the screen. Using duration measures, difference scores were also calculated, found by subtracting the duration of behavior directed towards the object-in-view from the duration of behavior towards the fringed screen. Three infants contributed only one of two possible trials because they refused to

engage in the second phase of the task, showing no reaching behaviors towards the fringed screen or the object in view. Actions on the fringed screen were further divided into two categories: purposeful, examining behaviors, as defined by fingering the fringe, reaching through the fringe, or lifting the fringe, versus non-reaching behaviors, such as pulling on the fringe or pulling on the wooden frame of the fringed screen. These classifications follow in the precedent of Ruff's (1986) studies involving infants' exploratory behaviors.

Frequency of behaviors was also analyzed and was coded as anytime infants switched from one behavior on the fringe to a different behavior on the fringe, or no action, or in a different order. For example, if an infant was pulling on the fringe for two seconds, then chose to reach through the fringe for three seconds, each action would be included in the duration of reaching measure, but would be counted as two separate behaviors directed towards the fringed screen. If an infant reached for his/her mom, then touched the fringe, then reached for the object in view, that would be coded as one behavior of "no action," one behavior towards the fringed screen, and one behavior towards the object in view. Thus, the duration of each action toward the fringed screen or the object in view could be averaged by dividing the number of behaviors from the total duration of those behaviors. A second independent observer, also blind to experimental condition as well as experimental hypothesis, coded 13 of the twenty-six infants tested in Experiment 1. Inter-observer reliabilities averaged 90%.

Results

Familiarization Trials

Two t-tests were used to analyze infants' willingness to search during the second and third familiarization trials. First, scores determined by experimenter's level of help given infant to grab the hidden object, were averaged and analyzed by means, using t-tests comparing same-sounds and different-sounds groups during familiarization trial 2 and another t-test to compare the two groups on familiarization trial 3. The analysis revealed no differences across groups during familiarization trial 2, $t(24) = -1.11$, $p>.05$, or familiarization trial 3, $t(24) = 0.59$, $p>.05$. Further analysis used a chi-square test, revealing that the two groups did not differ reliably in their distribution of scores, based on their willingness to search, for familiarization trial 2, $x^2 = 2.96$, $df = 3$, $p>.05$ or familiarization trial 3, $x^2 = 1.74$, $df = 3$, $p>.05$. See Tables 1 and 2 for crosstabulations. Infants needed approximately the same amount of help to retrieve the hidden object during familiarization trials.

Table 1. Experiment 1: Familiarization Trial 2 Crosstabulation

Familiarization Trial 2	Same Sounds	Different Sounds	Total
Partially 1	1	0	1
Partially 2	7	4	11
Fully Visible	3	7	10
Handed Toy	2	2	4
Total	13	13	26

Table 2. Experiment 1: Familiarization Trial 3 Crosstabulation.

Familiarization Trial 3	Same Sounds	Different Sounds	Total
Partially 1	1	2	3
Partially 2	4	5	9
Fully Visible	8	5	13
Handed Toy	0	1	1
Total	13	13	26

Test Trials

Infants' behavior on trials one and two were averaged and then analyzed for results. Infants' total duration of actions showed no effect by condition, $t(19.94) = -0.86$, $p>.05$, one-tailed test, equal variances not assumed. Sex showed no main effect on searching towards the fringe, $F(1,24) = 0.02$, $p>.05$, or towards the object in view, $F(1,24) = 1.44$, $p>.05$, nor did it have any interaction with the condition (same or different sounds), $F(1,24) = 0.21$, $p>.05$, $F(1,24) = 0.00$, $p>.05$, on searching towards the fringed screen or object, respectively. Results indicated a main effect of search location (fringed screen or object in view), that is, infants in both conditions (same-sounds and different-sounds) reached more to the fringed screen, $F(1,24) = 8.50$, $p<.01$, than the object in view. However, a repeated measures General Linear Model, using search location (fringed screen or object in view) as the within-subjects' factor and condition

(different sounds or same sounds) as the between-subjects' factor, revealed a significant

interaction between search location (the fringed screen or the object in view) and event

condition (same-sounds or different-sounds), $F(1,24) = 5.64$, $p<.05$.

Planned comparisons revealed that infants in the two conditions (different sounds

or same sounds) performed differently. Infants who heard two different sounds during

the display event showed reaching behavior directed significantly more toward the

fringed screen than toward the object in view, $t(12) = -3.77$, $p<.01$, one-tailed test;

implying that infants in the different-sounds condition perceived there to be two objects

involved in the event, with one object occluded behind the fringed screen. In contrast,

infants in the same-sounds condition reached about equally towards the fringed screen

and the object in view, $t(12) = -0.38$, $p>.05$, one-tailed test, giving the impression that

this group's response to the event was ambiguous; they perceived there could either be

one or two objects involved in the event. Furthermore, infants who heard different-

sounds reached significantly more toward the fringed screen than infants who heard

same-sounds, $t(24) = -1.82$, $p<.05$, one-tailed test, suggesting that infants in the

different-sounds group were more likely to search for a hidden object behind the screen,

than infants in the same-sounds group. See Table 3 for mean durations.

A significant effect of condition also existed for difference scores, found by

subtracting the duration of behavior directed towards the object-in-view from the

duration of behavior towards the fringed screen, $t(24) = -2.38$, $p<.025$, one-tailed test.

Non-parametric data echoed these results with 13/13 of the infants in the different-

sounds group spending more time acting on the fringed screen than the object, with a

binomial *p<*.001, while only 7/13 in the same-sounds condition spent more time acting

on the fringed screen than the object, with a binomial *p>*.05.

Table 3. Mean Durations of Reaching Behavior in Experiment 1, Property-Rich sounds.

Reaching Behavior Means (s)	Same Sounds (n=13)	Different Sounds (n=13)
Fringed Screen	2.96 *(2.56)*	5.49 *(4.32)*
Object-in-View	2.45 *(2.86)*	0.56 *(1.05)*
Difference Scores	0.50 *(4.79)*	4.94 *(4.72)*

Discussion

The infants in the different-sounds condition reached significantly more to the

fringed screen than the visible object, suggested that the infants interpreted the event as

involving two objects, one of which was hidden behind the screen at the end of the trials.

In contrast, the infants in the same-sounds condition reached about equally to the screen

and the visible objects, suggesting that they were ambiguous in their interpretation as to

whether one or two objects produced the two sounds. Finally, the different-sounds

infants reached significantly longer to the screen the same-sounds infants. These results

provide converging evidence for the conclusion that infants use property-rich sounds to

individuate objects. The infants responded as if they recognized that two distinct sounds

must be produced by two objects with discrete physical structures, and that the second

object must be behind the screen. They also responded as if they were unsure of whether

two identical sounds are produced by the same object or two separate but identical looking objects.

Experiment 2

To investigate whether young infants can use other types of sound for object individuation, Experiment 2 tested infants with property-poor sounds, sounds ambiguously tied to an object. Previous research conducted with a violation-of-expectation task suggested that young infants are more sensitive to property-rich than property-poor sounds (Wilcox et. al., 2006). Experiment 2 assessed 5- to 7-month-olds' ability to use property-poor sounds to individuate objects. Infants were presented with a same- or different-sounds event identical to that of Experiment 1 except that that the rattle sounds were replaced with electronic sounds made by a speaker connected to an mp3 player located inside the blue, egg-shaped object.

If the infants interpreted the event as involving two distinct objects (i.e., used the difference in sound to conclude that the objects seen to the left and the right side of the screen constituted two different objects), they should have spent more time searching for the second object behind the screen than reaching for the visible object. If the infants interpreted the different-sounds event as involving only a single object (i.e., failed to use the difference in sound to individuate the objects), they should have spent more time reaching for the visible object than searching behind the screen (since they did not expect a second object to be behind the screen).

Method

Participants

Twenty-two infants, 5 to 7 months old, 11 male, 11 female (*M* age = 6 months, 19 days; range = 5 months, 21 days to 7 months, 14 days) were included in the sample. Additionally, six tested babies were not included in the final sample because they failed to contribute at least one good trial: 4 failed to engage in the task (refusal to reach or failure to watch the occlusion events), 1 outlier (difference score was greater than two standard deviations above the mean), and one infant knocked over the hidden object at the start of the first trial, thereby compromising their experiences during the test. These infants were also randomly assigned to one of four conditions, formed by crossing event (same or different sounds) and sound (whistle-type sound or siren-type sound).

Apparatus, Events, Procedure

Identical procedure to Experiment 1 with the exception that sounds were produced electronically. From the data sample, four trials were excluded from analysis due to infants' failure to engage in the task: three did not see the complete occlusion sequence and one refused to reach toward the fringed screen or the object in view. To produce the electronic sounds of Experiment 2, an mp3 player with pre-programmed siren and "high wow" whistle sounds that could be played at the touch of a button was located inside the back of the blue, egg-shaped object. The property-poor sounds used for Experiment 2 were comparable to the analogous property-rich ones of Experiment 1 based on two grounds: (1) the "high wow" sound produced the same, high frequency as the rice sound from the first experiment, measuring at 4000Hz and higher (at 16000Hz)

during spikes while the siren sound measured at the same frequency as the rattle sound, orbiting 2250 - 3000 Hz, and (2) adults judged two property-rich sounds as equally likely to be produced by two different objects as the two property-poor sounds' likelihood to originate from two separate objects, $F(1,28) = 2.07$, $p>.05$. Behaviors were coded as in Experiment 1. A second independent observer, who was also blind to the experimental condition, as well as the experimental hypothesis, coded eleven of the 22 infants tested in Experiment 2. Inter-observer reliabilities averaged 96%.

Results

Familiarization Trials

Two t-tests were used to analyze infants' willingness to search during the second and third familiarization trials. First, scores were averaged and analyzed by means using t-tests to compare same-sounds and different-sounds groups during familiarization trial 2. A second t-test was used to compare the two groups on familiarization trial 3. The analysis revealed no differences across groups during familiarization trial 2, $t(20) = -0.55$, $p>.05$, or familiarization trial 3, $t(20) = -1.12$, $p>.05$. Supportive analysis used a chi-square test, also revealing that the two groups did not differ reliably in their distribution of scores, based on their willingness to search, for familiarization trial 2, $x^2 = 1.09$, $df = 3$, $p>.05$ or familiarization trial 3, $x^2 = 2.00$, $df = 3$, $p>.05$. See Tables 4 and 5 for crosstabulation. Infants needed approximately the same amount of help to retrieve the hidden object during familiarization trials.

Table 4. *Experiment 2: Familiarization Trial 2 Crosstabulation.*

Familiarization Trial 2	Same Sounds	Different Sounds	Total
Partially 1	1	0	1
Partially 2	4	4	8
Fully Visible	5	6	11
Handed Toy	1	1	2
Total	11	11	22

Table 5. *Experiment 2: Familiarization Trial 3 Crosstabulation.*

Familiarization Trial 3	Same Sounds	Different Sounds	Total
Partially 1	1	0	1
Partially 2	5	5	10
Fully Visible	5	5	10
Handed Toy	0	1	1
Total	11	11	22

Test Trials

Infants' behavior on trials one and two were averaged and then analyzed for results. Event condition proved no effect on infants' total duration of activity during the

experiment, $t(20) = -0.02$, $p>.05$. Sex showed no main effect on searching towards the fringe, $F(1,20) = 1.31$, $p>.05$, or towards the object in view, $F(1,20) = 0.09$, $p>.05$. Sex did not have any interaction with the condition (same or different sounds), $F(1,20) = 0.02$, $p>.05$, $F(1,20) = 0.12$, $p>.05$, on searching towards the fringed screen or object, respectively.

Findings include a significant interaction between search location (fringed screen or object-in-view) and event condition (same-sounds or different-sounds), $F(1,20) = 6.91$, $p<.025$. The trend was the opposite from what was found in Experiment 1. Planned comparisons revealed that, when using property-poor sounds, infants in the different-sounds condition reached slightly, though not significantly, more towards the object than the fringed screen, $t(10) = 1.72$, $p>.05$. On the other hand, infants in the same-sounds condition reached significantly more towards the fringed screen than the object in view, $t(10) = -2.52$, $p<.05$. Infants in the property-poor, different-sounds group did *not* spend more time acting on the fringed screen than the object. Only 4/11 in the different-sounds condition reached more for the fringed screen, with a binomial $p>.05$, while in the same-sounds condition, 10/11 spent more time acting on the fringed screen than the object, with a binomial $p<.01$. Table 6 shows mean durations of reaching behavior in Experiment 2.

Table 6. Mean Durations of Reaching Behavior in Experiment 2, Property-Poor Sounds.

Reaching Behavior Means (s)	Same Sounds (n=11)	Different Sounds (n=11)
Fringed Screen	3.98 (*1.81*)	2.67 (*2.96*)
Object-in-View	1.23 (*2.59*)	6.63 (*5.44*)
Difference Scores	2.74 (*3.60*)	-3.96 (*7.65*)

The results from the same-sounds condition of Experiment 2, property-poor sounds, seemed out of sync with the pattern of results found in the different-sounds condition in which infants were clearly not using the sounds for individuation. It makes little sense for infants hearing two different sounds to fail to individuate using property-poor sounds, but infants hearing two of the same sounds to interpret the two property-poor sounds as meaning two separate objects. We suspected that the infants in the property-poor, same-sounds condition took a different approach to the task than the infants in the other conditions of both Experiments 1 and 2. We suspected that infants in the property-poor, same-sounds event were not actively engaging in the task or responding in the same way the occlusion event. Rather, infants in this condition seemed to be more varied in their attentions and appeared to switch more rapidly from one behavior to another during the search phase than other groups. To investigate the extent to which the quality of the infants' behavior differed by experiment and/or condition, we recorded the frequency of infants' behaviors on the fringed screen.

The total numbers of infant behaviors, or frequency, were then used to calculate the average duration of each action. Using a general linear model with sound type (property-rich or property-poor) and event condition (same-sounds or different-sounds) as between-subject factors, a significant interaction between sound type and event condition existed on the length (in s) of each infant action, $F(1,44) = 5.84$, $p<.025$. An analysis compared the property-poor, same-sounds group with the property-rich, different sounds group, because both groups spent significantly greater durations of behaviors directed towards the fringed screen than the object in view. This comparison revealed that the infants in the property-rich, different sounds condition showed more perseverative reaching patterns, with each action lasting longer in duration than each action of the infants in the property-poor, same-sounds condition. To clarify, when infants touched the fringed screen, they touched it for a longer period of time before switching to another behavior, such as lifting the fringe or reaching towards the object in view or simply ceasing the action. The property-rich, different sounds group searched during the 20s with fewer transitions than the property-poor, same sounds group, and this difference *almost* reached significance, $t(20) = 4.23$, $p=.06$, one-tailed test. These data suggest that the infants in the property-rich, different sounds condition demonstrated more directed, persistent reaching towards the fringed screen (than the property-poor, same sounds condition). Table 7 shows mean number and length of screen behaviors in Experiment 2.

Table 7. Mean Number and Length of Screen Behaviors in Experiment 2, Property-Poor Sounds.

Fringed Screen Behaviors	Same-Sounds Number Acts – Action Length		Different-Sounds Number Acts – Action Length	
Property-Rich	1.92 (1.10)	1.23 (0.82)	2.62 (1.23)	2.42 (1.88)
Property-Poor	3.09 (1.80)	1.48 (0.90)	2.68 (2.71)	0.88 (0.67)

Discussion

Infants in the different-sounds condition reached more towards the object in view than the fringed screen, though not significantly more. Infants in the same-sounds condition had significantly more interaction with the fringed screen. These data suggest that infants failed to use property-poor sounds for object individuation, replicating prior results (Wilcox, et. al., 2006).

The pattern of behavior exhibited by the same-sounds condition, however, suggested that they were not engaged in the task but simply playing with the fringed screen. This might mean that the task was too hard, leading them to switch behaviors more quickly and more often than the other groups, exhibiting behavior more characteristic of play than a response to the event at hand.

One explanation of the data from Experiments 1 & 2 is that infants are more sensitive to property-rich than property-poor sounds for object individuation. An alternative argument is that the data might better be explained by another difference

between the sounds used in Experiments 1 & 2: the property-rich sounds were very

conjugate with the object's motion while the property-poor sounds were more

nonconjugate with the object's motion. This alternative interpretation suggests that

infants' ability to individuate using sound is not based on the sound category as

property-rich or property-poor, but rather, whether the object's sound is conjugate with

the object's motion. While an attempt was made to design both experiments to involve

sounds that occurred at the same time as the object's motion, the two properties were

more intimately synchronized in the property-rich condition than the property-poor

condition due to how these types of sound typically exist in nature. Both interpretations

of the data coincide with previous infant research concluding that infants use amodal

properties to help direct their attention to what is meaningful, coherent, and/or relevant

in complex environments. Amodal properties can be perceived through more than one

sense, such as temporal synchrony, rhythm, duration, and intensity (Bahrick, et al.,

2004). The property-poor sounds used in Experiment 2 lacked this relevant trait of

temporal synchrony. Thus, to address this idea more closely, Experiment 3 tested

infants' ability to individuate objects with specially constructed events using property-

poor, conjugate sounds.

Experiment 3

We attempted to make the property-poor sounds of Experiment 2 consistent with

the temporal synchrony of the object's motion. However, due to the nature of sound

production, using an electronic mp3 player inside the object, the property-rich sounds of

Experiment 1, using small, hard substances within the object, resulted in greater

temporal synchrony than the property-poor sounds. Experiment 3 was designed to test the extent to which temporal synchrony holds relevance for infants' object individuation. This experiment assessed 5- to 7-month-olds' ability to use conjugate, property-poor sounds to individuate objects, investigating the distinction of importance for property-rich sounds or simply property-poor sounds that are conjugate with the object's motion for object individuation. Infants were presented with property-poor, different sounds events identical to the different-sounds events of Experiment 2, with the following variations: (1) a "beeping" and a "buzzing" sound was used, and (2) the sounds associated with the egg-shaped objects were either conjugate or non-conjugate with the object's motion. In the conjugate condition, the egg-shaped object came into contact with the platform when shaken up-and-down by the experimenter during the occlusion event, making the sounds conjugate with the object's motion. In the non-conjugate condition, 2s of beeps followed by 2s of the object being shaken up-and-down, and one series of buzzes, also occurring apart from the 2s of object motion; the sounds occurred separately (in temporal senquence) from the object's up-and-down motion of contacting the platform base. On the contrary, in the conjugate condition, the "buzz" or "beep" always occurred simultaneously with the object making contact with the platform, making the sound conjugate with the object's motion. The sounds were produced from a small speaker and mp3 player contained within the object, as in Experiment 2.

If having sounds conjugate with object motion facilitates object individuation using property-poor sounds, leading the infants to interpret the event as involving two distinct objects, the infants should spend more time searching for the second object

behind the screen than reaching for the visible object. If using sounds conjugate with objects' motion fails to facilitate object individuation with property-poor sounds, and interpret the event as involving only a single object, they should spend more time reaching for the visible object than searching behind the screen (since they do not expect a second object to be behind the screen).

Method

Participants

Sixteen infants participated in this experiment, 9 males and 7 females (*M* age = 6 months, 15 days; range = 5 months, 23 days to 7 months, 13 days). Six additional babies were tested but excluded from the data analysis: 3 due to experimenter error, 2 for excessive fussiness, and 1 failed to engage in the task.

Apparatus, Events, Procedure

The apparatus, events, and procedure were identical to the different-sounds events of Experiment 2 with two exceptions: (1) infants were presented with different-sounds event only, and (2) the sounds were either conjugate or nonconjugate with the object's motion. Conjugate sounds were produced when an "egg" object was bounced on the table, but non-conjugate sounds occurred separate from object motion. To make the sounds conjugate with the object's motion, the experimenter shook the object up-and-down, making contact with platform at the same time as the "beep" or "buzz." For non-

conjugate sounds, the experimenter shook the object up-and-down for 2s, just as in the

conjugate condition, but the motion coincided with no sounds. Immediately following

the 2s of motion came the 2s of sound, "beep" or "buzzes". Infants heard buzzing on the

left side of the fringed screen, and then beeping on the opposite side, with order counter-

balanced. These sounds were produced by an mp3 player with pre-programmed

"beeping" and "buzzing" sounds, which could be played at the touch of a button in the

back of the object. From the sample, two infants only supplied one usable trial to one

with experimenter error and one infant not watching the occlusion sequence. Infant

actions were coded as in Experiments 1 and 2, with eight of the 16 infants coded by a

second observer who was also blind to the experimental hypothesis and condition. Inter-

observer reliabilities averaged 98%.

Results

Familiarization Trials

Two t-tests were used to analyze infants' willingness to search during the second

and third familiarization trials. First, scores were averaged and analyzed by means using

t-tests comparing same-sounds and different-sounds groups during familiarization trial 2

and another t-test to compare the two groups on familiarization trial 3. The analysis

revealed no differences across groups during familiarization trial 2, $t(12) = 0.33$, $p > .05$,

or familiarization trial 3, $t(12) = 0.00$, $p > .05$. To further illustrate this equality, a chi-

square test revealed that the two groups did not differ reliably in their distribution of

scores, based on their willingness to search, for familiarization trial 2, $x^2 = 2.50$, $df = 3$,

p>.05 or familiarization trial 3, x^2 = 4.80, *df* = 3, *p*>.05. See Tables 9 and 10 for

crosstabulations. Infants needed approximately the same amount of help to retrieve the

hidden object during familiarization trials.

Table 8. Experiment 3: Familiarization Trial 2 Crosstabulation.

Familiarization Trial 2	Conjugate	NonConjugate	Total
Partially 1	0	1	1
Partially 2	3	3	6
Fully Visible	5	3	8
Handed Toy	0	1	1
Total	8	8	16

Table 9. Experiment 3: Familiarization Trial 3 Crosstabulation.

Familiarization Trial 3	Conjugate	NonConjugate	Total
Partially 1	1	0	1
Partially 2	1	4	5
Fully Visible	6	3	9
Handed Toy	0	1	1
Total	8	8	16

Test Trials

As in the previous experiments, infants' behavior on trials one and two were averaged and analyzed for results, and event condition proved no main effect on infants' total amount of activity during the experiment, $t(14) = 0.38$, $p>.05$. Sex showed no main effect on behaviors towards the fringe, $F(1,12) = 0.31$, $p>.05$, or towards the object in view, $F(1,12) = 0.95$, $p>.05$, nor did it have any interaction with the condition (same or different sounds), $F(1,12) = 0.38$, $p>.05$, $F(1,12) = 1.13$, $p>.05$, on searching towards the fringed screen or object, respectively.

A main effect of search location existed, since both groups seemed to prefer the fringed screen, $F(1,14) = 6.88$, $p<.025$. Across conditions, results showed no significant interaction between search location and condition (conjugate or non-conjugate), $F(1,14) = 2.55$, $p>.05$; note that two different sounds were used during the event in both conditions of Experiment 3. Using planned comparisons, neither the non-conjugate group, $t(7) = -1.30$, $p>.05$, nor the conjugate group acted significantly more towards the fringed screen than the object in view, $t(7) = -2.30$, $p>.05$. This supports the idea that infants do not use property-poor sounds for object individuation, whether or not the sounds are conjugate or non-conjugate with the object's motion. To further explore these results, difference scores were calculated, the duration of action directed towards the object in view subtracted from the duration of action directed towards the fringed screen, to see whether either group was searching significantly more towards the fringed screen than the object in view.

If infants in the conjugate condition were interpreting the event differently (as involving two objects, with one hidden behind the fringed screen) than those in the nonconjugate group, we would expect a greater difference score on average in the conjugate condition than the nonconjugate condition. Though infants in both conditions of Experiment 3 acted more towards the fringed screen than the object in view, the difference scores did not significantly differ by condition (non-conjugate or conjugate), $t(9.48) = 1.60$, $p > .05$, equal variances not assumed. Reaching behavior means for Experiment 3 are shown in Table 10 with frequencies shown in Table 11. Nonparametric data reveals that 7/8 infants in the conjugate sounds condition reached more for the fringed screen than the object in view, with a binomial $p < .05$, while in the nonconjugate condition, 6/8 infants spent more time acting on the fringed screen than the object, with a binomial $p > .05$.

Table 10. Mean Durations of Reaching Behavior in Experiment 3, Conjugate (Property-poor) Sounds.

Reaching Behavior Means (s)	Non-Conjugate (n=8)	Conjugate (n=8)
Fringed Screen	3.88 (2.24)	7.86 (5.94)
Object-in-View	2.38 (2.49)	1.66 (2.85)
Difference Scores	1.51 (3.27)	6.21 (7.65)

Table 11. Mean Number and Length of Screen Behaviors in Experiment 3, Conjugate, Property-Poor Sounds.

Fringed Screen Behaviors	Different-Sounds Frequency–Each Action(s)			Different-Sounds Frequency–Each Action(s)	
Conjugate	3.50	2.21	Property-Rich	2.62	2.42
	(1.69)	(1.46)		(1.23)	(1.88)
NonConjugate	2.96	1.25	Property-Poor	2.68	0.88
	(1.47)	(0.64)		(2.71)	(0.67)

Discussion

In Experiment 3, the infants reached more for the fringed screen than the object in view in both conditions (conjugate and nonconjugate) though this difference was not significant in either case. These data suggest that temporal synchrony plays a role in infants' success at object individuation using sound, but sound type, property-rich or property-poor, is also important. This finding leads us to believe that the reliably determinant factor for infants' use of sound for object individuation is the type of sound, intrinsically tied to the object's physical properties (property-rich) or ambiguously connected to the object (property-poor) rather than if the sound is conjugate with the object's motion, although temporal synchrony is a typical characteristic of property-rich sounds.

Though the differences between the two conditions did not reach significance, infants in the conjugate condition tended to reach more to the fringed screen than the nonconjugate condition. Additionally, the non-parametric data conflicted with the continuous variable of search duration data; the binomial probabilities for searching more towards the fringed screen than the object reached significance in the conjugate condition but not in the nonconjugate condition. This fact is consistent with the previous research showing that temporal synchrony guides infants' attention and actions (Bahrick, 1993, 1987; Dodd, 1979; Spelke, 1979). However, infants showed large variability in their responses and search behavior to the conjugate, property-poor sounds event. This suggests that temporal synchrony alone was not enough to lead them to object individuation using property-poor sounds. Perhaps the young age group needs amodal synchrony on more than one level (in addition to temporal synchrony), but testing with older infants and using age as a predictor of performance would provide more clear insight on the developmental progression and usage of property-poor sounds for object individuation.

3. SUMMARY AND CONCLUSIONS

Distinguishing Property-rich vs. Property-poor Sounds

The results of Experiments 1 and 2 suggest that infants aged 5 to 7 months are more sensitive to property-rich than property-poor sounds when individuating objects. These results replicate those obtained in the looking time studies, and provide converging evidence for the conclusion that infants are more sensitive to some types of sounds than others (Wilcox et al., 2006).

This study investigated infants' ability to use sound for object individuation along a range of interrelatedness: (1) property-rich sounds intricately tied to the object's physical properties and motion on multiple levels, (2) property-poor sounds tied to the duration of object motion but unrelated to the object's physical properties, and (3) a sort of compromise in conjugate, property-poor sounds not related to the object's physical properties but closely tied to the duration of the object's motion as well as the rhythm and temporal synchrony between motion and sound. Young infants appear to reliably use property-rich sounds to individuate based on their interpretation of two different sounds as involving two different objects, in this case, in which one was hidden behind a fringed screen.

When presented with two different property-poor sounds, however, infants were more ambiguous in their interpretation and tended to judge the event as involving only one object, in fact, the one object in view. They gave little attention to the fringed screen that presumably masked no hidden object. An explanation for infants' use of the property-rich sounds earlier than the property-poor sounds exists in the Intersensory

Redundancy Hypothesis. Intersensory redundancy plays an impacting role in how infants learn about objects and the world.

The overlap of sensory information is abundant in the natural word, from birds flapping their wings, feet walking or tap-dancing, to talking faces. Infants, and adults to a lesser degree, use these amodal properties, those that can be perceived through more than one sense, such as synchrony, rhythm, duration, and intensity, to help direct their attention to what is meaningful, coherent, and/or relevant in complex environments. For this purpose, amodal properties guide attention more so than modality-specific, or unimodal properties such as color, pitch, and timbre (Bahrick, Lickliter, Flom, 2004). Property-rich sounds tend to exemplify intersensory redundancy, as a natural by-product of giving rich information about the object's physical properties. When the sound echoes a physical property of the object, the sound also tends to echo another sensory input besides the auditory realm. For example, shaking a container of small, metal beads produces a property-rich sound that also maps onto the intensity and rhythm of the object's motion. Thus, the sound provides information about the object's physical components and how they interact with the environment. The sound of a cell phone ring, however, does not map onto a unique motion of the cell phone (unless it is set on vibrate) nor give any information about the size of the cell phone or the composition of the cell phone. The ring tone could vary, depending on the owner's preference, failing to map onto any additional sensory input, such as intensity of the sound matching object motion.

Broader Impact

These results also compliment those obtained in the visual domain, where infants show greater sensitivity to form features, such as shape or size, than surface features, such as color, brightness, or pattern, for object individuation (Wilcox, 1999). Form features are intimately linked to objects and stable over time; they give information about the physical components of the object and how it interacts with other objects in its environment. Surface features are often arbitrarily and unreliably linked to objects; changing the color of an object does not change its physical structure. Surface features can also change when viewed under varying conditions, such as in and out of shadows. Surface features usually fail to give information about the object's physical structure and components, function, or how it will interact with other objects. Similarly, sounds may be more or less intimately tied to an object's physical properties and motion. Property-rich sounds, in the same way as form features, can give information about the nature of the object, its physical components and internal structure. Property-poor sounds, rather, are more arbitrarily linked to objects, making them less useful in object individuation and discerning information about an object's physical properties, function, or characteristics when interacting with other objects. Since property-rich sounds and form features seem to be a more reliable source of information for understanding an object, infants may find them more salient and useful for object individuation.

Underlying Basis for Using Sounds in Object Individuation

To investigate an alternative explanation for findings in Experiments 1 and 2, Experiment 3 provided a sort of compromise in conjugate, property-poor sounds, not

related to the object's physical properties but closely tied to the duration of the object's

motion as well as the rhythm and temporal synchrony between motion and sound.

Experiment 3 was designed to test the extent to which temporal synchrony, an example

of matching amodal properties, determined the success of young infants' use of sound

for object individuation (as opposed to the extent to which the sounds' close link to the

object's physical properties determines individuation). As evidenced in the use of

conjugate and non-conjugate sounds in Experiment 3, however, intersensory redundancy

on only one level (duration) may not be enough to encourage object individuation.

Results of Experiment 3 demonstrated that temporal synchrony does help performance,

but that the findings are not as robust at the findings of the property-rich conditions. This

suggests that temporal synchrony is important, helpful, and beneficial to infants' success

at object individuation, but having the sounds directly connected to the physical

properties of the objects is even more important.

The Intersensory Redundancy Hypothesis predicts selective attention to focus

on sensory stimulation that is redundantly specified, available in more than one

modality. Since infants come into the world with no prior knowledge to steer their

attentional energies, this effect of intersensory redundancy is more prominent during

infancy. One explanation for this phenomenon relates to perceptual development in that

intersensory redundancy allows infants (and those older) to selectively attend to related

aspects of stimulation from the single event of importance rather than be distracted by

surrounding events of irrelevant, yet concurrent stimulation. Thus, infants can know that

mom is talking to her, saying "hi there" instead of being confused by a ceiling fan or

television in the background because the visual input from mom's face matches the auditory cues in synchrony, duration, rhythm. With this being true, infants might pay more attention to property-rich sounds than property-poor sounds because they have more salience for infants, since they tend to have more overlapping features, greater intersensory redundancy.

Another possible basis for infants' seemingly greater sensitivity to property-rich sounds for object individuation could be related to prior experiences with sound. To investigate the potential role of experience leading babies to utilize property-rich sounds earlier than property-poor sounds for object individuation, we have begun an observational study in a lab setting called "Free Play." We observe parent-infant interactions and what types of sounds babies make of their own initiation, as well as the types of sounds they make as a result of parental encouragement and parents' play that results in sound production with toys.

Final Comments

In regards to intersensory representation of objects, infants can detect the temporal aspects of an object's sound as well as the spatial correspondence with the sounds' source (Bahrick, et al., 2004). Consequently, intersensory redundancy, or the lack thereof, is believed to guide selective attention as well as learning during early infancy, in part because redundantly specified properties are processed earlier than alternative types of stimuli during early development. Therefore, infants find sound, particularly sounds that are characteristically "property-rich" and clearly tied to the physical properties *and* synchronous with movement, as incomparably important in

object labeling due the amodal properties it appends, along with the intersensory redundancy hypothesis. Due to its perceptual cues, ties to physical properties, social importance, and amodal tendencies, sound holds a special influence in directing our attention to the point of interest or intrigue, enhancing infants' talents of labeling objects and forming representations.

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Selected Research Presentations:

Conference on The Society for Research in Child Development**,** Poster

March 31, 2007: "To shake or not to shake: The question of infants playing with sound"

International Conference on Infant Studies, Poster Presentation

June 22, 2006: "Shaking things up: Infants' use of sound information for object individuation"

Cognoscenti, Cognitive Seminar, Oral Presentation

May 1, 2006: "Shaking things up with a closer look at infants' use of sound and the role of Parent-Infant Interactions"

Texas A&M Student Research Week, Oral Presentation

March 28, 2006: "Shaking things up with a closer look at infants' use of sound and the role of Parent-Infant Interactions"

Teaching Experience:

Guest Lecturer, Developmental Psychology (PSYC 307) TAMU

Social Development and Attachment – July 16, 2007

Emotional Development and Attachment – October 4, 2006

Guest Lecturer, Introduction to Psychology (PSYC 107) TAMU

Developmental Psychology (in a nutshell) - September 21, 2006

Developmental Psychology (in a nutshell) – June 9, 2006