THE DIFFICULTIES OF APPLYING CATEGORY KNOWLEDGE GLEANED FROM 3-DIMENSIONAL EXPERIENCE TO 2-DIMENSIONAL CONTEXTS BY 7- TO 9-MONTH-OLD INFANTS

By

Jane A. Hirtle

Thesis

Submitted to the Faculty of the

Graduate School of Vanderbilt University

in partial fulfillment of the requirements

for the degree of

MASTER OF SCIENCE

in

Psychology

August, 2013

Nashville, Tennessee

Approved:	Date:
Amy Needham	July 15, 2013
Georgene Troseth	July 15, 2013

ACKNOWLEDGEMENTS

This research was supported by National Institutes of Health grant HD057120 to Amy Needham. A special thanks goes to Jennifer Norvell, Ariel Borten, Carolyne Kocot, Sarah Wiesen, and all the undergraduate research assistants in the Infant Learning Lab for their assistance in data collection. I would also like to thank the many families who so generously gave their time to participate in the studies. Most importantly, I thank my adviser Amy Needham, who first welcomed me into research when I was an undergraduate and since then has tirelessly advocated for me and given her invaluable help and advice every step of the way, as well as my parents Diana and Elvin, my sister Grace, my brother Ethan, and the many friends who supported and encouraged me on this project and in everything else. I am so lucky and so grateful to have you all.

TABLE OF CONTENTS

LIST OF FIGURES

CHAPTER I

INTRODUCTION

Previous research supports the idea that infants form categories of everything from faces to sounds to objects, and use these categories to create expectations, to detect violations of such expectations, and to perceive complex scenes involving exemplars from a familiar category in a top-down manner (Needham, Cantlon, & Ormsbee-Holley, 2006; Kovack-Lesh, Horst, & Oakes, 2008; Scott & Monesson, 2010; Scott, Pascalis, & Nelson, 2007). However, there is still much we do not know about how infants come to categorize objects and recognize new objects as exemplars of a familiar category, particularly as the field of infancy research and the world of the infant are changing. In infancy research, the recent advent and continuing popularity of eye-tracking technology allows us to more precisely measure and describe infant visual scanning of objects and scenes than ever before. In the world outside the lab, many infants are receiving exposure to a broader variety of media than before, including 2-dimensional static images of objects and 2-dimensional video representations on pre-recorded video, live video, and interactive touch screens. A growing body of research suggests that infants' and young children's perceptions of 2-dimensional representations of objects and scenes may differ from their perceptions of 3-dimensional objects and scenes, a fact that complicates many of our previous generalizations about object categorization in our youngest participants (Johnson, Bremner, Slater, Shuwairi, Mason, Spring, & Usherwood, 2012; Troseth, Pierroutsakos, & DeLoache, 2004). Can young infants use knowledge about 3-

dimensional objects, including category knowledge, to inform their perceptions of 2-dimensional objects and vice versa?

In light of recent changes in each of these areas, we must adapt and re-evaluate our previous conclusions about infant categorization and object perception. In the three experiments presented here, I adapted 3-dimensional stimuli used in a previous study examining infant categorization in 7.5- to 8-month-old infants. I tested 7- to 9-month-old infants' ability to create expectations of object behavior from 3-dimensional experience and detect violations of these expectations in two different 2-dimensional media, namely digital images and videos. Results indicate that infants struggle to extend category knowledge gleaned from everyday 3-dimensional experience to 2-dimensional contexts in order to detect violations of typical object behavior. Results suggest that the quality of the 2-dimensional representation (i.e., performance was superior with the video rather than static image stimuli) and the degree of prior 3-dimensional experience with category exemplars (i.e., performance with 2-dimensional stimuli was superior following enriched 3-dimensional experience) marginally improve infants' detection of violations. However, these improvements are inconsistent across the sample.

Infant Object Perception and Categorization

Most adults with a lifetime of varied video and computer exposure behind them easily perceive a variety of complex scenes involving 2- and 3-dimensional objects as coherent and predictable. For example, as you read this manuscript you easily perceive the letters as inextricably linked to the paper they rest upon, despite the gross differences in color and shape between the two. If you were to lift this paper, you would be shocked if all the letters were to slip off its surface and clatter to the ground. However, you do not assume that one page of this manuscript is indelibly connected to the other pages simply because of their similarities in color, shape, and pattern. Similarly, you have no difficulty perceiving the manuscript when viewed on a computer as entirely contained within the screen and impossible to grasp or drop, but if you were to watch a video of me handling my manuscript you would not be surprised to see me grasp or drop it. These perceptions are such a basic part of everyday life that we take them for granted. Interestingly, in both cases the clear expectation we have about how pages of a manuscript and the text written upon them will act run counter to an analysis of the visual world based on Gestalt principles of similarity. We perceive the words to be stuck to the page even though they look very different from the paper; we expect pages of the manuscript to be separate from each other even though they look highly similar to each other. So, our experiences are the critical component of these expectations. How do these seamless perceptions of the connections and separations between objects come to be? How do we traverse such wild differences in context to effortlessly apply our knowledge of how certain types of objects usually work in 3-dimensional experience to 2-dimensional experience? The answers to such questions can be found by examining the development of these abilities in infancy.

Infants develop the ability to perceive objects as separate or unified over the course of the first year of life (Johnson & Aslin, 1996; Kellman & Spelke, 1983; Slater, Johnson, Brown, & Badenoch, 1996; Slater, Morison, Somers, Mattock, Brown & Taylor, 1990). Between around 3.5 to 7.5 months of age, infants come to perceive object connections and separations based on object features such as color, shape, and pattern (Needham, 1998; Needham, 1999; Needham, 2000). However, features alone do not guide object segregation: even preverbal infants can use category knowledge to segregate objects into their component parts, or perceive objects that are distinct in color, shape, or texture as unified (Needham et al., 2006). Further, infants use category knowledge to create expectations for objects within those categories and their properties, and tend to look longer at events that violate these expectations than at events that follow them (Dueker, Modi, & Needham, 2003; Mandler & McDonough, 1996, 1998; Needham, Dueker, & Lockhead, 2005). Such categories appear to be built through experience with exemplars, just as expectations for individual objects and their behavior are built through experience (Dueker & Needham, 2005; Dueker et al., 2003; Goldstone, 1998; Kovack-Lesh et al., 2008; Mandler, 2004; Needham & Baillargeon, 1998; Needham & Modi, 1999; Needham, 2001; Needham et al., 2005; Quinn & Schyns, 2003; Scott et al., 2007).

Such research forms the basis of our understanding of infant object perception, but there are important limitations in how far we can apply our conclusions due in part to the methods used to conduct these studies in the past and to recent changes in the environments many infants are developing in. For the past thirty years research on infant object perception and cognition has relied heavily on looking time studies that used measures we now consider somewhat problematic, for reasons such as poor precision and potentially important issues with whether the objects used were real, 3-dimensional objects or representations on video screens. Current eye tracking systems allow us to much more quickly and easily gather specific data on looking time and gaze direction than is possible with human observers, but these benefits do not come without costs or caveats, including many significant and often perplexing effects on data collection and interpretation (see Aslin, 2007). One chief but often ignored complication is the heavy reliance of many eye tracking systems, particularly the remote systems favored in infancy research, on picture or video stimuli appearing on television or computer screens. While this might not initially seem significant, it is an often overlooked but important fact that in testing infants with video projections and video or image stimuli on television or computer screens, we are tacitly requiring them to transfer category knowledge of the 3-dimensional world to the 2-dimensional world. The implications of this change are extensive, as I will show.

Infant Exposure to and Perceptions of Videos and Images

Until the 1990s, infants typically received only incidental experience with video and little experience with video images compared to today's infants, due in large part to the lack of commercially available video products created specifically for infant audiences. Infants are typically inattentive to video that is not age-appropriate, so it is safe to say that infants before this time probably gleaned little from whatever meager exposure they happened to receive (Anderson & Pempek, 2005; Wartella, Richert, & Robb, 2010). Infant cognition research reflected this by either avoiding the topic of video with this age group entirely or implicitly assuming that infant responses to video and real life were similar (for an exception, see Johnson et al., 2012).

Indeed, early research on infant responses to video indicated few differences in how infants perceived real life versus video and other images. According to early studies, the ability to recognize the correspondence between photos of objects and the objects photos depict is unlearned (Barrera & Maurer, 1981; DeLoache, Strauss, & Maynard, 1979; Dirks & Gibson, 1977; Hochberg & Brooks, 1962; Johnson et al., 2012).

Early studies also demonstrated that infants appear to visually discriminate between 2-dimensional and 3-dimensional objects from birth, although they are less precocious in showing this discrimination in their reaching and touching behavior (Field, 1976; Slater, Rose, & Morison, 1984). In fact, 6-month-old infants often erroneously respond to images of objects in much the same way they do to real objects insofar as they may attempt to grasp or manipulate pictured objects, a finding replicated more recently with 9-month-old infants using both pictured objects and objects displayed on a video screen (DeLoache, Pierroutsakos, Uttal, Rosengren, & Gottlieb, 1998; Field, 1976; Pierroutsakos, 1999; Pierroutsakos & Troseth, 2003). Similar responses to videos as to direct experience have also been shown in older children: 14- and 24-month-old toddlers were able to imitate behaviors demonstrated to them by persons on television, even after a time delay (Meltzoff, 1988). Given these findings, it is unsurprising that we often tend to behave not only as researchers but also as caregivers, at least implicitly, as if there are few and insignificant differences in infants' and young children's responses to video and images versus direct experience.

However, in recent decades much has occurred to challenge that belief. First, infants are receiving far more experience with video and photographs than they did previously. With the advent of 'Baby Einstein' in the late 1990s, there has been a remarkable boom in video products geared toward infants. The modern baby of today is exposed to videos like *Your Baby Can Read*, television programs like *Teletubbies*, smart phone applications like 'iBabyPhone' and 'Babysitter2Go,' and even television channels like 'Baby First TV.' Despite strong recommendations against infant exposure to video by the American Academy of Pediatrics, recent surveys of children's television and video viewing report that around 40% of infants view some television or videos by 3 months of age, a figure that rises to 90% by 24 months of age (Christakis, 2009; Zimmerman, Christakis, & Meltzoff, 2007). Infants are also receiving exposure to more advanced and elaborate video and images than have been widely studied previously, including interactive video on touch screens and instant digital photography. Due to the rapidity of this change, we do not yet know precisely what implications this has for either infant perception or cognition specifically or development on the grand scale (DeLoache & Chiong, 2009).

Second, more recent research suggests that early responses to and understanding of images and videos are more complex than previously thought. Numerous authors have documented what has come to be known as the video deficit, a term describing the poor performance of children under 2.5 years in situations that require them to learn from or use information from video sources in comparison to performance in situations depending on information or learning from live sources. This effect has been demonstrated in a variety of domains, including imitation, word learning, object retrieval, and self-recognition (Anderson & Pempek, 2005; Barr & Hayne, 1999; Brito, Barr, McIntyre, & Simcock, 2012; DeLoache, Chiong, Sherman, Islam, Vanderborght, Troseth, Strouse, & O'Doherty, 2010; Hayne, Herbert, & Simcock, 2003; Roseberry, Hirsh-Pasek, Parish-Morris, & Golinkoff, 2009; Schmidt, Crawley-David, & Anderson, 2007; Suddendorf, Simcock, & Nielsen, 2007; Troseth & DeLoache, 1998). A variety of experiences have been demonstrated to ameliorate the video deficit and improve young children's performance, including training with contingency between video and direct experience, increasing the length of video exposure or the video teaching or demonstration, and the simplifying the nature of the task to be learned or imitated from video (Barr, Muentener, & Garcia, 2007; DeoCampo & Hudson, 2009; DeoCampo, 2003; Fidler, Zack, & Barr, 2010; Nielsen, Simcock, & Jenkins, 2008; Strouse & Troseth, 2008; Troseth, 2003; Troseth, Saylor, & Archer, 2006).

Despite such a large and varied body of research, the source of the deficit remains somewhat controversial. Some argue that the root of the problem rests in the symbolic nature of images and videos, and the difficulty of maintaining a dual representation of a video or image both as a thing in and of itself and as a symbol of something else simultaneously (DeLoache, 2004; Pierroutsakos, 1999; Pierroutsakos & Troseth, 2003; Troseth & DeLoache, 1998). From this perspective, infants do not regard 2-dimensional objects and people as identical to their 3-dimensional counterparts, but rather are confused and initially default to similar treatment of both, perhaps as an exploratory measure (Troseth et al., 2004). Others argue that the perceptual challenges presented by 2-dimensional images and videos in comparison to direct experience (including the sparseness of depth cues) cause the deficit although this account has not received much support, even from the researchers who initially proposed it (Schmitt & Anderson, 2002; Schmidt et al., 2007). Yet another explanation that could account for the video deficit, although it is not exclusively applied in or to that literature, is the broader issue of transfer of knowledge and learning between contexts (Barnat, Klein, & Meltzoff, 1996; Barr, 2010; Borovsky & Rovee-Collier, 1990; Shields & Rovee-Collier, 1992). In this view, transfer between the 2-dimensional and the 3-dimensional and vice versa presents a particular difficulty to infants under a year of age due to constraints on memory and representation that are resolved by increasing age and experience (Barr, 2010; Hayne, Boniface, & Barr, 2000). Regardless of the explanation, this impressive body of work strongly indicates that infant perceptions of video and images versus real life may be quite different, or in any case that the treatment of both types of stimuli as similar obscures the nuances of how each medium is perceived and related to the others by infant and toddler research participants.

Implications for Infant Perceptual and Cognitive Research

The confluence of these recent changes within and outside the psychology laboratory creates not only an opportunity for expanding and adapting our methods and conclusions, but also a necessity for doing so. Outside the lab, infants are bombarded with video and images that likely have profound impacts on development in multiple domains (Wartella et al., 2010). Within the lab, eye-tracking systems are becoming even more popular, with the consequence that researchers rely more frequently on video and image stimuli. As infants continue to receive increasing and more varied experience with 2-dimensional objects, it is imperative that we replicate and expand upon previous studies for the purpose of reaffirming, refining, and if necessary, altering our previous theories to suit the changing research landscape of infant cognition and perception.

Current Study

The current research does precisely this. In the following three experiments, I adapt and expand upon a previous study conducted by Needham et al. (2006) to examine infants' application of category knowledge to objects in televised still images and objects on video. I adapted 3-dimensional stimuli used on a small stage by Needham et al.

(2006) for a 2-dimensional display on an eye-tracking device. The basic stimuli consisted of either still images (Experiment 1) or dynamic videos (Experiments 2 & 3) of a person manipulating a partially occluded toy key ring. In each experiment, the key ring toy can be perceived as either a single unified object through top-down application of category knowledge, or perceived as two separate objects (ring and keys) through bottom-up processing of the shape, color, and texture differences between the parts. ‘

In a between-subjects design modeled on Needham et al.’s (2006) Experiment 1, in each of my three experiments 7- to 9-month-old infants viewed either an event that followed the expectations engendered by a top-down approach (i.e., joint movement of the component parts, referred to as a Move-together event) or violated those expectations (i.e., separate movement of the parts, referred to as a Move-apart event). Movement was implied in the consecutive still images in Experiment 1, whereas in the dynamic videos in Experiments 2 and 3 the entire movement was shown.

Certain hypotheses were constant across all three experiments. In each experiment, I predicted that infants utilizing category knowledge would fixate more on the portion of the eye-tracking screen wherein the keys should be expected to appear over the course of the movement in the Move-apart event, as the failure of the keys to appear in this area would violate the expectations of category knowledge. If infants did not utilize category knowledge, I predicted they would fixate more on this same portion of the eye-tracking screen during the movement in the Move-together event. In the latter case, the appearance of the keys in this are would violate the expectations of bottom-up processing.

In addition to my hypotheses pertaining to fixation behavior, I also formed predictions based on infants' exposure to key ring objects prior to participating in the studies. In Needham et al. (2006), an age effect was found: 8.5-month-old infants showed looking behavior consistent with category knowledge application, while 7-month-old infants showed looking behavior consistent with bottom-up processing. This effect was attributed to greater accumulated key ring experience in the older rather than the younger group of infants, as parents of 8.5-month-olds uniformly reported maximum levels of prior experience on a simple questionnaire. In order to test this hypothesis, I gathered more detailed data on infants' prior experiences with key ring objects in all three experiments, and directly manipulated infants' experience with key ring toys in Experiment 3.

CHAPTER II

EXPERIMENT ONE

Introduction

In my first experiment, infants saw a series of still images depicting a hand moving the ring of a key ring toy. In the Move-together condition the keys of the toy appeared to move with the ring, while in the second image of the Move-apart condition the keys of the toy remained stationary while the ring moved alone. These stimuli differed from those of Needham et al.'s (2006) Experiment 1 in one important way. In Needham et al. (2006), the objects were moved horizontally away from the infant, but this change in depth was found to be nearly imperceptible when shown in still images. For this reason, the objects in this experiment were moved vertically upward. Although this change made the movement obvious, as a side effect the keys did not move naturalistically on the ring but rather clung to the ring in a clump.

I predicted three different outcomes based on infants' use of top-down processing (i.e., category knowledge application) versus bottom-up processing (i.e., basic parsing principles) of the test stimuli, and infants' sensitivity or insensitivity to unnatural object behavior in still images.

In the first possible outcome, infants would apply categorical knowledge based on experiences with real key rings outside the lab and would be sensitive to unnatural object behavior in images. If this were the case, infants would expect the ring and keys to move jointly, and they would expect the keys to move loosely on the ring rather than in a clump. Both conditions would violate one expectation or the other: in the Move-apart condition, infants' expectation that the keys would move with the ring would be violated, while in the Move-together condition, infants' expectation that the keys would move loosely on the ring would be violated. Therefore, if infants apply categorical knowledge to the scene and are sensitive to unnatural object behavior I predicted equally high fixations at the area of the screen in which the keys are expected to appear, and there would be no significant difference between the conditions. I further predicted that infants' amount of prior experience with key ring objects would correlate positively with their fixations on the aforementioned area of the screen.

In the second possible outcome, infants would apply categorical knowledge but would not be sensitive to unnatural object behavior in images. Infants would expect the ring and keys to move jointly, but they would have no particular expectations about whether the keys should move in a clump or loosely. The Move-apart condition violates this expectation because the keys do not move with the ring and never appear in the portion of the screen where they are expected to appear. However, so long as joint movement occurs, unnatural movement is irrelevant, thus the Move-together condition is perfectly acceptable. Therefore, if infants apply categorical knowledge to the scene but are *not* sensitive to unnatural object behavior I predicted significantly higher fixations at the expected location of the keys in the Move-apart rather than the Move-together condition. In this case, I predicted that only infants in the Move-apart condition would show the aforementioned positive correlation between amount of prior experience and number of fixations on the expected location of the keys.

In the third and final possible outcome, infants would not apply categorical knowledge to the scene, and they would be sensitive to unnatural object behavior in general but not to unnatural object behavior that is specific to key ring objects. Infants would perceive the scene as consisting of separate objects that should not move together. If infants do not apply categorical knowledge of key ring objects, they cannot form expectations about what would constitute "natural" or "unnatural" behavior for that specific type of object. This interpretation does not assume that infants do not **have** category knowledge of key ring objects, only that they do not **apply** category knowledge of key rings to the scene.

Although infants may not apply category knowledge to the scenes, they may apply more general expectations about object behavior such as an unsupported object (e.g., the keys) will fall and objects which are different in texture, color, and shape (e.g., the individual keys) are discrete objects (Baillargeon & Hanko-Summers, 1990; Baillargeon, Needham, & DeVos, 1992; Needham & Baillargeon, 1993; Needham, 1998; Needham, 1999; Needham, 2000). The Move-together condition violates infants' expectation because the keys move with the ring, but also because the keys appear unsupported and because the individual keys move as a unit. In contrast, the separate movement of the ring in the Move-apart condition is expected.

Importantly, it is impossible to tell if infants were engaging only one or both of these perceptual processes in the occurrence of this third outcome, as my predicted results would be the same: infants would show significantly higher numbers of fixations at the expected location of the keys in the Move-together rather than the Move-apart condition. In this case, it is unlikely that infants' amount of prior experience with key rings would correlate with number of fixations on the expected location of the keys. Although a given infant may have category knowledge of key rings from extensive experience with such objects, if that knowledge is not applied to the images in the experiment there will likely be no apparent correlation between fixation patterns and prior experience.

Method

Participants

Participants were 40 healthy, full-term infants (17 male) ranging in age from 7 months, 1 day to 9 months, 3 days (M = 7 months, 29 days, SD = 16.78 days). Half of the infants viewed the Move-apart event, and the other half viewed the Move-together event. Data from an additional 23 infants were collected and eliminated, three due to experimenter error, six due to failure to complete the questionnaire, three due to excessive fussiness, and eleven due to inadequate eye-tracking samples gathered during the study. Inadequate eye-tracking samples were typically the result of a combination of technical difficulties with the eye-tracking hardware and high inattentiveness on the part of the infant. Less than 30% samples out of 100% possible eye-tracking samples were considered inadequate.

Infants' names in all of the experiments reported here were obtained from the Tennessee State Birth Records, and families were contacted via phone call or email. Parents were offered a small infant toy or an infant T-shirt featuring our lab logo as a thank-you for participating.

Apparatus

The testing room contained an infant high chair positioned approximately 50cm away from a Tobii T120 eye-tracker. Test event videos were created and displayed using Tobii Studio software (Version 2.1.14).

The display in the test event images consisted of a white floor, a mottled beige wall, and a white platform with a key ring toy resting on the platform (see Fig. 1 and Fig. 2). The platform consisted of white Plexiglas base and a white rectangular screen. The base measured $15cm^2$ and 12mm thick, and the rectangular screen measured 15cm tall by 5cm wide. The rectangular screen was in front of the base and connected to it, and extended upward with approximately 4cm of the base showing on the left side of the screen and approximately 6cm of the base showing on the right side of the screen.

The display key ring consisted of a plastic ring painted bright blue measuring approximately 3mm thick, 1cm wide, and 6.5cm in diameter, and three brightly colored plastic keys (one green, one pink, and one purple). Each key was approximately 7.5cm long and 5.5cm wide at its widest point. The key ring rested on the platform with the keys stacked one on top of the other such that both the ring and the three keys were visible, but the rectangular screen obscured the connection between these parts. Approximately 25% of the ring was visible on the left side of the rectangular screen. The keys were affixed to each other with rubber cement.

To produce the Move-apart event, the ring was cut into a C-shape and arranged around the stacked keys such that the keys were disconnected from the ring but would appear connected to it, and the ring would appear to be a whole and continuous circle behind the rectangular screen.

To produce the Move-together event, an identical key ring was created and arranged on the support such that the ring looped through the keys and the keys were looped through the ring. As mentioned previously, the keys were cemented together to prevent the keys from slipping behind the rectangular screen and out of sight when the ring was lifted vertically during the test event.

Test event images were taken using a stationary Canon PowerShot A1100IS digital camera. The platform was located roughly in the center of the frame of each image, with about 5.5cm of space on each side, approximately 5.5cm of space between the top of the screen and the top of the frame, and the bottom edge of the platform about 2.5cm from the bottom of the frame.

Each infant saw a familiarization that consisted of two identical images, and three trials of a movement event. Each trial consisted of three images, the exact contents of which are described below. In all images, the first author manipulated the objects with her bare hand. Only her wrist and hand without jewelry or clothing was visible in the test event images.

Events

Move-apart event

Each trial of the Move-apart event consisted of three consecutive still images. See Figure 1 for a depiction of the Move-apart event in Experiment 1. The first image was identical to the familiarization image, namely, a motionless hand grasping the ring of the key ring toy with the thumb and four fingers of her left hand. The second image depicted a motionless hand holding the ring in the same manner as in the familiarization image (i.e., with the same fingers on the left hand), but the ring was lifted to the top of the rectangular screen such that 75% of the ring was visible in a C-shape around the left and top edges of the screen, with the keys still resting in their original position on the white base. The third image was identical to the first image. The first, second, and third images of all three trials are referred to collectively henceforth as Pre-Movement Image, Movement Image, and Post-Movement Image, respectively.

Move-together event

The Move-together event was identical to the Move-apart event with the following exceptions. See Figure 2 for a depiction of the Move-together event in Experiment 1. The second image depicted a motionless hand holding the ring in the same manner as in the familiarization image (i.e., with the same fingers on the left hand), but the ring was lifted to the top of the rectangular screen such that 75% of the ring was visible in a C-shape around the left and top edges of the screen, with the keys lifted to the top of the rectangular screen and extending beyond the right edge of the screen. The first, second, and third images of all three trials are referred to collectively henceforth as Pre-Movement Image, Movement Image, and Post-Movement Image, respectively.

Procedure

During the consenting process, each infant's parent completed a questionnaire pertaining to the infant's prior experience seeing, touching, and mouthing real and toy key rings. Then, each infant sat either in a high chair with his or her parent seated directly behind them out of the infant's sight, or in his or her parent's lap. The infant faced the display screen of the eye-tracking device with the screen angled at approximately 25 degrees from the vertical to ensure that the infant viewed the screen head-on from his or her position. The infant's head was approximately 50cm from the screen.

An experimenter sat at a desk beside the infant at a distance of about 60cm to the right of the high chair or parent's chair behind a black curtain to reduce the distraction of the experimenter herself as well as the lighted screen of the computer used to run the experiment.

A calibration sequence preceded any experimental content. In this sequence, the infant's point of gaze (POG) was calibrated with the eye-tracker. A looming attention-getter (i.e., a colorful lobster toy) appeared at 9 different locations on the monitor in turn, and the infant looked at each one. To complete the calibration, the eye tracker compared the infant's POG with the known coordinates of each of the 9 locations in which the attention-getter appeared.

To begin the experiment proper, the infant first saw two identical, consecutive still familiarization images followed by three trials of the same test event. The infant either saw only Move-apart test events, or only Move-together test events. Each familiarization image was displayed for 5 seconds for a total of 10 seconds of familiarization.

Each test event consisted of three consecutive images, each appearing for 5 seconds for a total of 15 seconds per trial of the test event. Between each familiarization image and test event was a still image of a rainbow-colored pinwheel on a neutral background that was displayed for 2 seconds each time it appeared. The pinwheel never appeared in between the three images that composed a test event trial, only between trials.

Areas of Interest (AOIs)

Four Areas of Interest (AOIs) were designated on the images shown to infants (see Fig. 3). These AOIs allow us to characterize relevant looking behaviors (number of fixations, length of fixations) produced by the infants. Henceforth, all AOIs will be referred to by the following names: AOI 1 is the Original Keys Location, AOI 2 is the Final Keys Location, AOI 3 is the Original Ring Location, and AOI 4 is the Final Ring Location. All other areas on the screen are grouped together and defined as “Not AOI.”

As stated previously, infants in Experiment 1 saw a series of 3 images in each test trial, for a total of 9 images in the entire Test Event sequence. The first image and third image are identical, while in the second image the movement occurs. For the remainder of Experiment One, “the Test Event” refers to all three trials (nine images) taken together, whereas “the Movement Image” refers to the second image of each trial (three images) taken together. The AOI that will receive the lion’s share of my attention is the Final Keys Location, particularly during the second image.

Measures

Fixations were defined using Tobii ClearView software according to the I-VT (Velocity-Threshold Identification fixation filter) outlined by Salvucci and Goldberg (2000). The velocity threshold was set at the default of 35 (i.e., 2.11 pixels/ms when measuring at 60-Hz).

Fixation Count (the **number** of fixations within an AOI) was the basic measure used, and all other measures are derived from it. Two different types of analyses were conducted using this measure. I used the first type, analyses conducted on the summed Fixation Counts on all AOIs and "Not AOI," to ensure that there were no significant unpredicted effects of certain variables (e.g., Sex or Condition) on overall Fixation Count during Familiarization and the Test Event, or on Questionnaire Score. The second type of analyses pertained directly to my a priori hypotheses and examined the predicted effect of Condition on Fixation Count on a specific AOI in a particular group of images such as the Test Event or the Movement Image.

In addition to this measure of infant looking, as mentioned previously each infant's prior experience with key rings outside the lab was measured with a parent questionnaire. The Questionnaire Score is how many points an infant's parent reported, expressed as a percentage of the total points possible. This measure was taken in order to test Needham et al.'s (2006) hypothesis that the age effects seen in that study were driven by the older infants in their studies having accumulated greater experience with key rings than the younger infants had (i.e., that age correlates positively with experience).

Results and Discussion

Preliminary Analyses

Every parent reported that his or her infant had at least some prior experience with real or toy key rings or both, although the degree of experience reported was variable. With a score of 100 points indicating that the parent reported the maximum amount of experience possible on the questionnaire, the mean reported experience score was 41.61 points, with a standard deviation of 18.37 points.

I investigated the effects of total Fixation Count during Familiarization (Move-apart or Move-together) via a 2 (Sex) X 2 (Condition) analysis of variance (ANOVA). Infants fixated about an equal number of times at the familiarization images, regardless of whether they went on to see the Move-apart event ($M = 11.00$, $SD = 5.50$) or Move-together event ($M = 10.11$, $SD = 4.39$). There was no significant sex difference in infants' Fixation Count ($F = .029$, $p = .866$), and no interaction between Sex and Condition ($F = .251$, $p = .620$).

I found no significant correlation between Age and Questionnaire Score (*Pearson's* $r = .105$, $p = .518$), suggesting that infants do not gain more experience with key rings as they get older. This finding fails to corroborate the hypothesis of Needham et al. (2006). There are numerous possible reasons for this unexpected result. First, parents whose infants participated in Needham et al. (2006) reported uniformly high levels of prior experience with key ring toys on a simple questionnaire. On the more complex questionnaire used in the current study, parents reported much more variable levels of key ring experience. Further, in the time since Needham et al. (2006) was conducted there may have been a decrease in the popularity and production of key ring toys for infants, greater variability in the features of real and toy key ring exemplars due to the increasing use of keyless button-operated car door openers, and a decrease in the visibility of key rings to infants due to the popularity button-operated car door openers, which can be activated from within a pocket or otherwise out of an infant's sight. These factors may explain not only the lack of correlation between Age and Questionnaire Score, but also the high variability I saw in infants' prior experience with key rings.

A 2 (Sex) X 2 (Condition) ANOVA on Questionnaire Score yielded no main effect of Condition ($F = .763$, $p = .388$), no main effect of Sex ($F = .002$, $p = .966$), and no interaction ($F = .257$, $p = .616$). Importantly, no parent reported that his or her child had absolutely no prior key ring experience, indicating that each infant had some knowledge of key ring objects prior to participation. For this reason, I continued with the primary analyses that would address my other hypotheses about the application of categorical knowledge.

The data were collapsed across Sex for subsequent analyses.

Primary Analyses

I predicted that infants would not fixate more often in one condition or the other overall. To examine this, I conducted an independent samples t-test on Condition and Fixation Count during the Test Event. This test yielded no significant effect of Condition, with infants in the Move-together condition fixating about the same total number of times on the test events as infants in the Move-apart condition (40.50 and 36.95 respectively; $t = -.665$, $p = .510$).

I next carried out the analyses that would answer my hypotheses. First, I investigated the effect of Condition on Fixation Count on the Final Keys Location AOI only in Test Event via an independent samples t-test, and found a significant effect of Condition. Infants in the Move-together condition fixated significantly more often on the

Final Keys Location AOI than did infants in the Move-apart condition (6.67 and .45 respectively; $t = -7.107$, $p = .000$).

To test my prediction that this effect also would be apparent in the Movement Image data specifically as well as in the Test Event data in general, I conducted an independent samples t-test to examine Fixation Count on the Final Keys Location AOI on the Movement Image. This test yielded a significant effect of Condition on Fixation Count on the Final Keys Location AOI for the Movement Image. Infants in the Move-together condition fixated significantly more often on this AOI than infants in the Move-apart condition (5.44 and 0.23 respectively; $t = -7.894$, $p = .000$). See Figure 4 for a graph representing this finding.

A closer look at the data revealed that all but one infant in the Move-together condition fixated on the Final Keys Location AOI in the Movement Image, and infants in this condition in general focused their fixations on this AOI and the Final Ring Location AOI. In contrast, only three infants in the Move-apart condition fixated on the Final Keys Location AOI in the Movement Image. The vast majority of infants in the Move-apart condition fixated primarily on the Final Ring Location AOI and the Original Keys Location AOI. These results are consistent with the third possible outcome I predicted, which indicates that categorical knowledge was not applied. However, as mentioned previously this result alone does not specify if infants' fixations were driven by the joint movement of keys and ring, the common movement of the individual keys, the lack of support of the keys, or a combination of these factors. See Figure 5 for a graph representing Move-together and Move-apart infants' average fixation counts on all AOIs.

Finally, I conducted tests to determine whether there was a significant correlation between Questionnaire Score and fixation patterns during the Test Event overall or the Movement Image specifically. This analysis revealed no significant correlation between the amount of key ring experience reported by parents and total Fixation Count on the Final Keys Location AOI during the Test Event (*Pearson's* $r = -.028$, $p = .865$). There was also no significant correlation between Questionnaire Score and total Fixation Count on the Final Keys Location AOI during the Movement Image (*Pearson's* $r = .029$, $p = .860$). This was not unexpected given that the third possible outcome I predicted had occurred: although category knowledge may not have been applied, I cannot be certain that it does not exist in the minds of any infant in the study, particularly given the fairly high prior experience some parents reported on the questionnaires.

In sum, infants fixated most often on the Final Keys Location AOI in the Move-together condition rather than in the Move-apart condition during the Test Event in general and the Movement Image specifically. A parsimonious explanation of this finding would be that infants fixate on this area simply because their attention is captured by the apparent change in location of one of the objects onscreen, not by bottom-up processing of the scene. However, if this were the case, infants should fixate about the same number of times on both the Final Ring Location AOI and the Final Keys Location AOI, since in Movement Image both of these AOIs contain an object (either keys or ring) that shifted position between the first and second images in the movement event sequence. However, this was not the case: an independent samples t-test revealed that Fixation Count on the Final Ring Location AOI in the Movement Image was not significantly different between Conditions ($t = 1.229$, $p = .227$).

I propose a more probable explanation: infants in Experiment 1 failed to apply categorical knowledge of key ring objects to the scene and therefore perceived the display in a bottom-up manner. Infants did not expect the keys and ring to move jointly, and reacted to the joint movement of the ring and keys in the Move-together condition by fixating on the unexpected appearance of the keys (the Final Keys Location AOI). Further, it is likely that infants fixated on the Final Keys Location AOI in the Move-together Test Event and Movement Image not only because they did **not** employ categorical knowledge of key ring objects specifically, but also because they **did** employ knowledge about objects in general. If infants parsed the ring and keys as separate objects due to lower-level features such as color and texture, they would likely have parsed the individual keys unit into separate pieces as well. In this case, the keys would form three unconnected objects rather than one, meaning that the common movement of the keys is itself a violation of expectation, to say nothing of the movement of the ring in relation to the keys. In addition, previous research indicates that beginning around 4.5 months of age and developing further over the course of the following 3 to 5 months, infants become aware that objects must have adequate support if they are to rest stably on a surface and not fall (Baillargeon & Hanko-Summers, 1990; Baillargeon et al., 1992; Needham & Baillargeon, 1993). With this in mind, the 7- to 9-month-old infants in this study should have understood that objects that do not have adequate support should fall, and may have fixated on the Final Keys Location AOI as a reaction to the failure of the apparently unsupported keys to do so.

Experiment 1 alone does not resolve these issues, nor does it answer the question of whether or not infants *have* a mental category of key ring objects, only that they do not apply it to these stimuli. As previously mentioned, every participant in Experiment 1 had some prior experience with key ring objects, and indeed some infants had a great deal of experience. At least some of these infants likely had category knowledge of the objects in question – why then did they not apply it? In light of the research on video and still images discussed previously, the medium may be partially to blame.

The use of static images could have made it difficult for infants to apply knowledge of objects they have gleaned from the dynamic, continuous events and interactions they experience in the real world. Although I had anticipated that infants would be able to infer movement over the series of images utilized in Experiment 1, it is possible that this method of displaying the stimuli presented an insurmountable challenge to infants because it does not show the full movement event. Previous research indicates that 4-month-old infants cannot perceive 3-dimensional form from a single static image or even multiple static images viewing the same object from different angles, as infants in Experiment 1 would have had to do in order to recognize the similarity between the 2-dimensional key ring they were viewing and the 3-dimensional key rings that had experienced previously (Kellman, 1984). A more recent study by Baldwin et al (2001) indicated that 10- to 11-month-old infants noted unnatural breaks in a video stream of dynamic action (e.g., looking longer at videos in which a human's action on an object was disrupted in the middle of the action rather than at the completion of the action), suggesting that even at this age infants may be conscious of the realistic flow of action and sensitive to unnatural pauses in action (Baldwin, Baird, Saylor, & Clark, 2001). Finally, yet another study indicated that 2-, 3.5-, and 5-year-old children are less attentive to incomprehensible video (e.g., video with randomly reordered shots) than comprehensible video (Anderson, Lorch, Field, & Sanders, 1981). With this in mind, if infants in Experiment 1 were confused by the stream of images and perceived no connection between them, they may have been less attentive to the events they were being shown. In light of these other studies' findings, the breaks in the depiction of the movement in Experiment 1 could have demanded a better ability to relate static images to each other than infants of this age are capable of doing, unintentionally highlighted the disparity between the stimuli onscreen and real experience, or simply distracted the infants from the occurrences onscreen.

Therefore, even infants with comparatively high previous key ring experience might have had difficulty recognizing that the display in Experiment 1 contained a novel exemplar from a category of familiar objects. This explanation fits with the lack of correlation between infants' questionnaire scores and Fixation Count on the Final Keys Location AOI in the Move-apart condition: infants with sufficient category knowledge of key ring objects should have recognized the display onscreen as a key ring, and consequently should have fixated more frequently on the Final Keys Location AOI in the Move-apart condition as an indication that their expectation of joint movement had been violated, but this was not the case. This issue was addressed in Experiment 2 by using dynamic videos rather than static images to portray the movement events. Further, in Experiment 2 the keys moved loosely on the ring rather than in a clump to more faithfully imitate real, 3-dimensional experience.

CHAPTER III

EXPERIMENT TWO

Introduction

In my second experiment, the use of more naturalistic dynamic video portrayals of the movement events allowed me to confine my hypotheses solely to the use of category knowledge. If infants applied categorical knowledge to the events, they would expect the keys to appear in the Final Keys Location AOI while the movement was occurring, and to be present there by the completion of the movement. The events in the Move-together condition would fulfill this expectation, while the events of the Move-apart condition would violate it. Therefore, if infants employed category knowledge, I predicted that infants in the Move-apart condition would fixate more often on the Final Keys Location AOI than would infants in the Move-together condition during the Test Event in general and the Movement portion of the Test Event specifically. If infants did not employ category knowledge, I predicted the reverse effect, with higher fixations in the Final Keys Location AOI by infants in the Move-together condition rather than in the Move-apart condition.

Further, I predicted that if category knowledge was employed then infants' amount of prior experience would positively correlate with Fixation Count on the Final Keys Location AOI during the Test Event in general and the Movement portion of the Test Event specifically. If infants did not use category knowledge, I predicted there would be no significant correlation between these variables.

Method

Participants

Participants were 19 healthy, full-term infants (10 male) ranging in age from 7 months, 0 days to 9 months, 23 days (*M* = 8 months, 0 days, *SD* = 24 days). Half of the infants viewed the Move-apart event, and the other half viewed the Move-together event. Data from an additional 15 infants were collected and eliminated, three due to experimenter error, one due to technical error, two due to excessive fussiness, and nine due to inadequate eye-tracking samples gathered during the study.

Apparatus

The apparatus was identical to that used in Experiment 1, with the following exceptions.

The display in the test event videos consisted of a white floor, a mottled beige wall, and a white support with a key ring toy resting atop the support (see Fig. 6 and Fig. 7). The white support consisted of a white box (10.5cm X 10.5cm X 10.5cm) with a trapezoidal screen atop it (21cm long X 5cm wide) extending from the upper right corner of the top of the box off the left edge. The key ring consisted of a ring measuring approximately 0.5cm thick and 6.5cm in diameter composed of wire covered in bright blue electrical tape, and three brightly colored plastic keys (one green, one pink, and one purple). Each key was approximately 7.5cm long and 5.5cm wide at its widest point. In both test events, the key ring rested on the support with the keys stacked one on top of the other such that both the ring and the three keys were visible, but the trapezoidal screen obscured the connection between these parts.

Test event videos were video-recorded from the same position as the still photos were taken in Experiment 1 using a stationary Sony Handycam HDDD 2000x Digital Zoom camcorder.

The Move-apart event in Experiment 2 was produced in the same manner as in Experiment 1 (i.e., by affixing the keys to each other with rubber cement and arranging a C-shaped ring around the stacked keys). To produce the Move-together event in Experiment 2, an identical key ring was created and arranged on the support so the keys were stacked but not affixed to each other. The ring looped through the keys such that the keys were connected to the ring and moved smoothly on the ring if the ring was manipulated.

Both test event videos were silent, brightly lit, and lasted 18 seconds. In both videos, a female research assistant manipulated the objects with her bare hand. Only her forearm with no jewelry or clothing was visible in the test event videos.

Events

Move-apart event

Each trial of the Move-apart event consisted of a single video. See Figure 6 for a series of stills depicting the Move-apart event. The beginning of the test event video was identical to the familiarization video, with the key ring toy resting motionless on the support. After approximately 2 seconds of no action, the research assistant's left hand entered the frame from the left side moving to the right, grasped the ring with her thumb and index finger, paused briefly, and then pulled the ring horizontally to the left for approximately 5 seconds, until finally pausing for approximately 5 seconds with the ring poised at the edge of the trapezoidal screen. The video then ended. When the hand reached its final resting position, 75% of the ring was visible in a C-shape around the far left and top edges of the trapezoidal screen. Throughout the video the keys remained motionless in their original position on the platform.

Move-together event

See Figure 7 for a series of stills depicting the Move-together event. The Move-together event was identical to the Move-apart event, with the following exceptions.

As the hand pulled the ring, the keys moved with the ring, disappearing briefly behind the trapezoidal screen and then swinging down naturally into the space below the trapezoidal screen to the left side of the white box. When the hand reached its final resting position, 75% of the ring was visible in a C-shape around the far left and top edges of the trapezoidal screen and the keys hung loosely downward underneath the trapezoidal screen to the left of the white box.

Procedure

The procedure of Experiment 2 was identical to that of Experiment 1, with the following exceptions. After the calibration sequence, the infant first saw two identical, consecutive familiarization videos followed by three trials of the same test event video. The infant saw either only Move-apart test event videos, or only Move-together test event videos. Each familiarization video lasted 4 seconds for a total of 8 seconds of familiarization. The familiarization video consisted of the toy key ring toy resting motionless on the support for the entirety of the video.

Summing across all three trials, there was approximately 54 seconds of test video. Between each familiarization video and test event video a still image of a rainbow-colored pinwheel on a neutral background was displayed for 2 seconds.

Areas of Interest (AOIs)

Five areas of interest (AOIs) were designated on the videos shown to infants (see Fig. 8). Henceforth, all AOIs will be referred to by the following names: AOI 1 is the Original Keys Location, AOI 2 is the Final Keys Location, AOI 3 is the Original Ring Location, AOI 4 is the Final Ring Location, and AOI 5 is the Ring Move Location. All other areas on the screen are grouped together and defined as "Not AOI."

As in Experiment 1, the Final Keys Location AOI is of primary interest. As before, the keys never appear in the Final Keys Location AOI in the Move-apart event, but they do appear in the Final Keys Location AOI in the Move-together event just before the hand stops moving.

Measures

Questionnaire Scores were calculated and Fixations defined according to the same method used in Experiment 1. Also as in Experiment 1, unless specifically stated all analyses reported herein were conducted using the total Fixation Count as defined in Experiment 1.

Results and Discussion

Preliminary Analyses

Every parent reported that his or her infant had at least some prior experience with real or toy key rings or both, and the amount of experience reported was variable. Parents of infants in Experiment 2 reported amounts of prior experience (*M* = 47.96, *SD* = 17.05) comparable to that reported by parents in Experiment 1.

I conducted a 2 (Sex) X 2 (Condition) ANOVA on the effects of total Fixation Count during Familiarization, and found that infants fixated about an equal number of times at the familiarization images regardless of Condition (*F* = .633, *p* = .439; *M* = 10.88, *SD* = 5.74 for Move-apart infants, *M* = 9.09, *SD* = 4.91 for Move-together infants), with no significant sex differences (*F* = 3.154, *p* = .096) and no interaction (*F* = 1.915, *p* = .187).

A 2 (Sex) X 2 (Condition) ANOVA on the effects of Questionnaire Score yielded no main effect of Condition (*F* = .363, *p* = .556) or Sex (*F* = 3.473, *p* = .082), and no interaction (*F* = .142, *p* = .712).

For this reason, the data were collapsed across Sex variables for subsequent analyses.

I found a significant positive correlation between Age and Questionnaire Score (*Pearson's r* = .491, *p* = .033), which suggests that infants do gain more experience with key rings as they age in accordance with the hypothesis of Needham et al. (2006). Following the results of Experiment 1, I had not predicted that infants' prior experience with key ring objects would correlate positively with age and was surprised to find this result in Experiment 2. However, after combining the samples of Experiment 1 and

Experiment 2 and subjecting the resulting sample to a two-tailed test of correlation, I found that a positive correlation between Age and Questionnaire Score failed to reach significance (*Pearson's r* = .245, *p* = .062), once again failing to support Needham et al.'s (2006) original hypothesis. These findings indicate that infants' exposure to key ring objects prior to their participation in these experiments was highly variable and that infants in these more recent experiments received less overall experience with key rings than did infants in the Needham et al. (2006) studies. Yet, there seems to be a mild increase, if not a statistically significant one, in infants' experience with key ring objects with increasing age.

Primary Analyses

As in Experiment 1, I predicted that infants would not fixate more often during the test events in one condition or the other overall. To test this prediction I conducted an independent samples t-test on the effect of Condition on infants' Fixation Count during the test events and found no significant effect of Condition. As predicted, infants fixated a similar number of times in both the Move-apart and Move-together conditions (t = .329, p = .742).

My next analyses directly addressed my hypotheses. An independent samples t-test on Condition and Fixation Count on the Final Keys Location AOI in all test events yielded a significant effect of Condition (t = -4.062, p = .001). Infants who viewed the Move-together event fixated significantly more often on this AOI than did infants in the Move-apart event (M = 5.09, SD = 2.427 and M = 1.25, SD = 1.282, respectively). This result mirrors the results of Experiment 1, and suggests that infants did not employ category knowledge. However, it is worth noting that infants in the Move-apart condition in Experiment 2 fixated more often on the Final Keys Location AOI than did infants in the Move-apart condition in Experiment 1 (M = 1.25, SD = 1.282, and M = .455, SD = .963, respectively).

At this point in my analyses, I decided to take a closer look at infants' fixation patterns over the course of the movement event and its completion. It occurred to me that based on the questionnaire findings, infants in both conditions were equally likely to have a mental category of key ring objects. Whichever infants, if any, applied a category of key ring objects would expect the keys to appear in the Final Keys Location AOI over the course of the movement, and would therefore fixate on this area at that time. For infants in the Move-apart condition, this expectation would be violated as the movement continued, which should lead to increased fixations on the Final Keys Location AOI during the course of the movement. Move-together infants, who experience no violation of expectation, would be unlikely to fixate frequently on this area during the movement. However, by the completion of the movement infants in the Move-together condition would likely fixate on the Final Keys Location AOI far more than infants in the Move-apart condition would regardless of whether they used category knowledge or not: for the infants not using category knowledge the appearance o the keys in the Final Keys Location AOI would be surprising and therefore receive high fixations, whereas infants applying category knowledge would likely still fixate on this area because it was now filled with attractive, colorful, moving keys. By this line of reasoning, if category knowledge was applied, I would predict that infants in the Move-apart condition should fixate more often on the Final Keys Location AOI **during** the movement than should infants in the Move-together condition, whereas infants in the Move-together condition should fixate more often on the Final Keys Location AOI **following** the completion of the movement than infants in the Move-apart condition. However, if only this second prediction proves to be true, then it is unlikely that category knowledge has been applied.

To investigate this hypothesis, I conducted an independent samples t-test on Condition and Fixation Count on the Final Keys Location AOI **during** movement time only, which yielded a null effect ($t = -1.383$, $p = .185$). This analysis indicated that there was no difference between groups in whether they fixated **expectantly** on the Final Keys Location AOI, and indeed average Fixation Counts on this AOI for infants in both conditions were quite low, as can be seen in Figure 9 ($M = .25$, $SD = .463$ in Move-apart, and $M = .818$, $SD = .982$ in Move-together). A closer examination of the data indicated that only two infants in the Move-apart condition fixated on the Final Keys Location AOI during the movement portion of the test trials, and each of these infants fixated only once on this AOI. These infants were both around 7 months, 15 days of age, one female with moderate prior experience (Questionnaire Score: 50%) with key ring objects and the other a male with almost no prior experience (Questionnaire Score: 9.67%). Overall, infants in the Move-apart condition primarily fixated on the ring as it moved. For more details on which AOIs infants tended to fixate upon in each Condition during the Movement event, consult Figure 10.

Six infants in the Move-together condition fixated on the Final Keys Location AOI during the movement, half of whom were male and half female, ranging in age from 7 months to 8 months, 9 days with questionnaire scores ranging from 24.19% to 64.52%. As in the Move-apart condition, infants in the Move-together condition primarily fixated on the ring as it moved. However, in the case of the Move-together infants this is not necessarily an indication of expectation: in the Move-together condition the keys appear briefly in this AOI in the last moments of the movement. Therefore, it is unclear from this data alone if infants in the Move-together condition were fixating on this AOI **expectantly** early on in the movement or **reactively** later on as the keys appeared.

From this analysis, it appears that the few infants in Move-apart that fixated at all on the Final Keys Location AOI were not persistent in their fixations as if reacting to a violation of expectation, and judging by their questionnaire scores they are unlikely to have fixated in the first place due to expectations from category knowledge. This further suggests that infants were not using category knowledge. I then continued with a series of analyses to examine infants' fixations **following** the completion of the movement.

An independent samples t-test revealed a significant effect of Condition on Fixation Count on the Final Keys Location AOI during this portion of the test trials (t = -4.331, p = .001): infants in the Move-together condition (M = 3.91, SD = 2.256) fixated more frequently on this AOI than did infants in the Move-apart condition, as can be seen in Figure 11 (M = .14, SD = .378). All of the infants in the Move-together condition fixated on the Final Keys Location AOI following the completion of the movement, in fact infants in this condition fixated almost exclusively on the Final Keys AOI except for some fixations on the Final Ring Location AOI. This casts further doubt that the six infants who fixated on this AOI during the movement were doing so expectantly, and suggests rather that infants in the Move-together condition fixated **reactively** on the keys' appearance in the Final Keys Location AOI. Once again, infants in the Move-apart trials did not fixate on the Final Keys Location AOI very often at all. Indeed, only one infant in the Move-apart condition fixated on this AOI and she only did so once. Interestingly this was the same female that fixated on the Final Keys Location AOI during the movement (Questionnaire Score: 50%). Overall, infants in the Move-apart condition fixated primarily on the Final Ring Location AOI. For more details on which AOIs infants tended to fixate upon in each Condition following the Movement event, consult Figure 12.

In light of the significant correlation between Age and Questionnaire Score found during the preliminary analyses, I conducted a series of two-tailed tests of correlation to determine if Age or Questionnaire Score were correlated with Fixation Count on all AOIs during the test trials, on the Final Keys Location AOI during the movement portion of the test trials, and on the Final Keys Location AOI following the completion of the movement portion of the test trials. None of these correlational tests revealed a significant result (all p values > .05).

Overall, the results of Experiment 2 fail to support an application of category knowledge explanation. Infants in the Move-together condition fixated more often on the Final Keys Location AOI than did infants in the Move-apart condition over the course of all trials, although this was not the case during the portions of the test trials in which movement was still occurring but rather during the portions of the test trials in which the movement was already complete. This indicates that infants in the Move-together condition looked **reactively** rather than **expectantly** to the keys' appearance in the Final Keys Location AOI during the Move-together test trials: infants in the Move-together condition noticed the sudden appearance, accompanied by movement and color, of the keys in the Final Keys Location AOI and then fixated upon it, but we have no concrete evidence that they rightfully perceived the keys and ring as a unified object and predicted the keys' appearance in the Final Keys Location AOI.

This explanation for the results is supported by the findings of the correlational tests: infants' fixation upon the Final Keys Location AOI during the movement portion and following the movement appeared to be unrelated to infants' prior knowledge of key ring objects as measured by the parent-report questionnaire. If infants used category knowledge to perceive the display depicted in the test trials, I predicted a positive correlation between prior experience with key ring objects as measured by the questionnaire and Fixation Count upon the Final Keys Location AOI during the movement, as an indication of infants' expectation that the keys would appear in this area. Further, I predicted that the infants who appeared to fixate expectantly (i.e., during the movement) on the Final Keys Location AOI would have higher questionnaire scores than infants who did not if category knowledge was applied. However, this was not the case.

In both Experiment 1 and Experiment 2, infants showed different responses to 2-dimensional stimuli, either image or video, than infants did to the 3-dimensional stimuli used in Needham et al. (2006), with the overall conclusion that all infants are failing to apply category knowledge of key ring objects to the 2-dimensional displays. However, while it is possible that this failure is due to the transfer of the stimuli from 3 dimensions to 2 dimensions, it may also be due in part to infants' highly variable prior experience with key rings as indicated by the Questionnaire Scores. It is possible that many infants in these experiments did not have sufficient experience with key ring objects to have created a mental category of key ring objects and recognize an exemplar from that category in 2 or 3 dimensions.

To resolve this issue, I directly manipulated infants' experience with key ring objects in Experiment 3 prior to testing the infants with the same video stimuli used in Experiment 2. In Experiment 3, I recruited infants to visit the lab twice over the course of two weeks. During the first visit I demonstrated to parents how to play with their infants with a selection of four key ring toys, and infants viewed images of the same four key rings on the eye-tracking device. Following two weeks of at-home experience with these key ring toys, infants returned to the lab and viewed the test events as well as images of the four take-home key rings and an image of the key ring used in the experimental videos. The repeated presentation of images of key rings were intended to track any changes in infants' fixation behaviors as the key rings became more familiar in case preferences for a particular key ring developed, and to gauge infants' ability to differentiate between the familiar take-home key rings and the novel key ring from the experimental videos.

CHAPTER IV

EXPERIMENT THREE

Introduction

In my third experiment, my predictions were only slightly different from those of Experiment 2. Following extended experience with key ring exemplars, I predicted that infants would create mental categories of key rings regardless of age or amount of prior experience. If all infants utilized category knowledge to perceive the events onscreen, I predicted that they would fixate expectantly on the Final Keys Location AOI during the movement event in both conditions, and would fixate more often on that area if over the course of the movement the keys fail to appear there as is the case in the Move-apart condition. However, by the end of the movement event I expected infants would realize if their expectation had been fulfilled or not, and therefore behave reactively by either fixating in the Final Keys Location AOI a great deal if there were anything in that location (i.e., the colorful keys in the Move-together condition) or very little if there were nothing in that location (i.e., empty space in the Move-apart condition). In simple terms, if category knowledge was employed, then I predicted that infants in the Move-apart condition would fixate more frequently on the Final Keys Location AOI **during** the movement event than infants in the Move-together condition would, but that infants in the Move-apart condition would fixate less frequently on the Final Keys Location AOI than infants in the Move-together condition **following** the movement event. If category knowledge were not employed, the results would be the similar to those of Experiment 2, i.e., with no significant difference between infants in the Move-apart condition and the Move-together condition **during** the movement event and infants in the Move-together condition fixating more often on the Final Keys Location AOI **following** the movement event. In this third experiment, the latter result would indicate not a lack of category knowledge, but a lack of its application.

I made several further predictions about the images of key ring toys. I predicted that all infants would differentiate between the familiar exemplars and the novel exemplar, displaying this differentiation through higher Fixation Count on the novel exemplar than on the familiar exemplars. I also predicted that infants would not show a preference for any particular take-home key ring toy over any other, but that there would be an overall increase in Fixation Count on the key ring images between the first and second visits. This latter prediction is based on the idea that by the second visit infants' experiences with the key rings from their at-home play sessions would create familiarity with the objects as 3-dimensional, graspable toys rather than 2-dimensional static images. In this way, although the keys depicted in the static images should be recognizable to the infants, the actual experience of them as 2-dimensional would be fairly novel to the infants and therefore increase infants' visual exploration.

Method

Participants

Participants were 20 healthy, full-term infants (10 male) ranging in age from 6 months, 17 days to 8 months, 23 days (*M* = 7 months, 10 days, *SD* = 16.37 days) at the first visit, and 7 months, 6 days to 9 months, 11 days (*M* = 7 months, 26 days, *SD* = 16.04

days) at the second visit. The average number of days between the first and second visits was 16.15 days, with a standard deviation of 2.73 days. Half of the infants viewed the Move-apart event, and the other half viewed the Move-together event at the second visit. Data from an additional 23 infants were collected and eliminated, two due to technical errors, three due to failure to complete both visits of the study, one due to failure to complete the at-home play log, one due to excessive fussiness, and sixteen due to inadequate eye-tracking samples gathered during one or both visits.

Apparatus

The eye-tracking apparatus and testing room was identical to that of Experiment 2, with the following exceptions.

Experiment 3 also involved a play portion of the procedure, which utilized a different apparatus and testing room than the eye-tracking portion. For the play portion, the infant, parent, and experimenter sat alone in a quiet, well-lit room. The infant was seated on his or her parent's lap while the parent sat at a U-shaped table. The infant was seated in such a way that their arms rested comfortably on the tabletop and the table surrounded them on three sides. The experimenter was seated across the table and slightly to the left of the parent and infant. Four video cameras situated on the ceiling and the walls directly in front of, to the left of, and to the right of the infant recorded the entirety of the play portion.

The toys used in the play session were four commercially available infant key ring toys. Each key ring toy differed from the others in their exact colors, textures, size, and shape, but each key ring toy was brightly colored and made of plastic. The first key ring toy (Key Ring 1) was composed of a white plastic ring measuring 1cm thick and 7.5cm in diameter, with four identical keys in different colors (one blue, one green, one yellow, and one red) each measuring 9.5cm long and 5.5cm at its widest point. The second key ring toy (Key Ring 2) was composed of a blue and white polka dot oblong ring measuring 7mm thick and 8.5cm in diameter in one direction and 7cm in diameter in the opposite direction, with three slightly differently shaped keys in different colors (one blue and red, one purple and green, and one yellow and orange) each measuring 7.5cm long and 6cm at its widest point. The third key ring toy (Key Ring 3) was composed of a blue plastic ring measuring 0.5cm thick and 6cm in diameter, with five slightly differently shaped keys in different colors (one blue, one green, one orange, one yellow, and one red) each measuring 6.5cm long and 3.5cm at its widest point. The fourth and final key ring toy (Key Ring 4) was composed of a light blue plastic ring measuring 1cm thick and 6.5cm in diameter, with three slightly differently shaped keys in different colors (one blue, one yellow, and one orange and red) each measuring 7cm long and 6cm at its widest point.

Events

The Move-apart test event videos and the Move-together test event videos were identical to those used in Experiment 2.

Procedure

Visit 1 Procedure

Each infant's parent completed the same questionnaire used in Experiments 1 and 2 during the first visit. Following this, the first visit involved two portions: a play portion and an eye-tracking portion. The play portion of the procedure preceded the eye-tracking portion of the procedure for all infants.

For the play portion of the procedure, the infant, parent, and experimenter were seated as described in the Apparatus section. The experimenter then presented each of the four sets of key ring toys individually. This was done by grasping the ring of the key ring toy, holding it aloft approximately 30cm away from the infant at the infant's eye-level, and shaking the toy to catch the infant's attention for approximately 2 seconds. The experimenter then placed the key ring toy in front of the infant within easy reach. The infant was allowed 30 seconds to play freely with the key ring toy before it was retrieved. The experimenter then repeated this procedure for the other three key ring toys. The order in which the key ring toys were presented was randomized.

After the experimenter had presented each key ring toy individually, she then presented all four key rings simultaneously. Grasping each key ring toy by its ring, she held all four key rings aloft with both hands approximately 30cm away from the infant at the infant's eye-level, and shook the toys to catch the infant's attention for approximately 2 seconds. The experimenter then placed all four key ring toys in front of the infant within easy reach. The infant was allowed 30 seconds to play freely with the key ring toys before all four were retrieved.

The parent was then instructed to play with the four key ring toys at home with the infant in the same manner as demonstrated by the experimenter for between 10 to 20 minutes a day. The second visit was scheduled 14 days after the first visit, and parents were instructed to play with their infant every day if possible, but for no less than 9 days. Parents were given an at-home play log with play instructions and a calendar along with the take-home key ring toys, and asked to keep track of the days they played, the length of time of each play session, and any other relevant notes about their play sessions. This completed the play portion.

The eye-tracking portion of the procedure was identical to that of Experiment 2, with the following exceptions.

The infant first saw two identical, consecutive familiarization videos. Each familiarization video lasted 4 seconds for a total of 8 seconds of familiarization. The familiarization video consisted of the toy key ring toy resting motionless on the support for the entirety of the video. The key ring toy appearing in the videos in Experiment 3 was identical to the key ring toy that had appeared in Experiments 1 and 2.

Following the familiarization videos, the infant then saw a series of still images of the key ring toys used for take-home play (see Fig. 13). Images were presented in pairs, so infants saw two key ring toys resting flat on a plain white background, with the keys arranged loosely hanging off the ring and the ring, the keys, and the connection between these parts fully visible. Infants saw these pairs in randomized order such that they saw each possible pairing of the four key ring toys used for take-home play, and saw each key ring toy on the left and the right side of the screen. This created a total of 12 pairs. After every three pairs, a rainbow pinwheel image was presented for 2 seconds in order to maintain attention. Each pair appeared for 2 seconds, for a total of 24 seconds of display time.

Visit 2 Procedure

The procedure followed in Visit 2 was identical to that of Visit 1 with the following exceptions.

For the play portion of the procedure, the infant, parent, and experimenter were seated as described in the Apparatus section. The at-home play log was retrieved from the parent, and then the parent was instructed to present the take-home key ring toys to his or her infant in the same manner they did during the at-home play sessions. The parent was given 2 minutes to play with the key ring toys and the infant. This was done to ensure that at-home play sessions were similar to the in-lab play sessions. All infants included herein had completed at least 9 at-home play sessions ($M = 12$, $SD = 1.83$) of at least 10 minutes each. This concluded the play portion.

The eye-tracking portion of the procedure was identical to that of Experiment 2, with the following exceptions.

The infant first saw two identical, consecutive familiarization videos followed by three trials of the same test event video. The infant saw either only Move-apart test event videos, or only Move-together test event videos. Each familiarization video lasted 4 seconds for a total of 8 seconds of familiarization. The familiarization video consisted of the key ring resting motionless on the support for the entirety of the video.

Each test event video lasted 18 seconds for a total of 54 seconds of test video. Each familiarization video and test event video was interspersed with a still image of a rainbow-colored pinwheel on a neutral background that was displayed for 2 seconds each time it appeared.

Following all test event video trials, the infant then saw a series of still images of the key ring toys used for take-home play and the key ring used in the test event videos (see Fig. 13). These images were shown following rather than preceding the test event videos so as not to prime infants to perceive the objects in the test events as key rings, but rather to allow infants to spontaneously perceive them as such or not. As in the first visit, key ring toy images were presented in pairs, so the infants viewed two key ring toys resting flat on a plain white background, with the keys arranged loosely hanging off the ring and the ring, the keys, and the connection between these parts fully visible. Infants saw these pairs in randomized order such that they saw each possible pairing of the four key ring toys used for take-home play, and saw each key ring toy on the left and the right side of the screen. This created a total of 25 pairs. After every five pairs, a rainbow pinwheel image was presented for 2 seconds in order to maintain attention. Each image appeared for 2 seconds, for a total of 50 seconds of display time.

Areas of Interest (AOIs)

On the experimental videos, the same five areas of interest (AOIs) were designated as were used in Experiment 2. On the static images of the key ring toys, each entire key ring object was designated as an AOI and labeled in the following manner: Image 1 is Key Ring 1, Image 2 is Key Ring 2, Image 3 is Key Ring 3, Image 4 is Key Ring 4, and Image 5 is the Experimental Key Ring, as this is the key ring that was used in the experimental videos (see Fig. 14).

For the experimental videos, the Final Keys Location AOI is of primary interest as in the preceding two experiments. As in Experiments 1 and 2, note that the keys never appear in the Final Keys Location AOI in the Move-apart event, but they do appear in the Final Keys Location AOI in the Move-together event. In the Move-together event, keys do not appear in the Final Keys Location AOI until near the end of the movement event, and they remain there for the remainder of the trial following the movement event.

Measures

Questionnaire Scores were calculated and Fixations were defined according to the same method used in Experiments 1 and 2. As in the previous experiments, unless specifically stated all analyses on the experimental video data reported herein were conducted using the total Fixation Count as defined in Experiments 1 and 2. Unless a particular key ring is specifically delineated, all analyses on the static images data reported herein were conducted using the sum of all Fixation Counts on Key Rings 1, 2, 3, and 4. Unless otherwise stated, Key Ring 5 is excluded from these sums because it was seen during the second visit only.

Results and Discussion

Preliminary Analyses

As in the first two experiments, every parent reported that his or her infant had at least some prior experience with real or toy key rings or both, and the amount of experience reported was variable. However, parents of infants in Experiment 3 reported amounts of prior experience (*M* = 38.14, *SD* = 17.11) comparable to that reported by parents in Experiments 1 and 2.

I conducted a 2 (Sex) X 2 (Condition) ANOVA on the effects of total Fixation Count during Familiarization, yielding no significant effects of Condition (F = 1.514, p = .236; *M* = 11.00, *SD* = 3.712 for Move-apart infants, *M* = 8.20, *SD* = 5.940 for Move-together infants) or Sex (F = .278, p = .605) and no interaction (F = .772, p = .393).

A 2 (Sex) X 2 (Condition) ANOVA on Questionnaire Score yielded no main effect of Condition (F = .516, p = .483) or Sex (F = .223, p = .643), and no interaction (F = 1.274, p = .276).

A 2 (Sex) X 2 (Condition) ANOVA on Fixation Count on all take-home key ring images during the first visit yielded no main effect of either Condition (F = .002, p = .963) or Sex (F = 1.003, p = .332), and no interaction (F = .275, p = .607). A 2 (Sex) X 2 (Condition) ANOVA on Fixation Count on all take-home key ring images during the second visit also yielded no main effect of either Condition (F = .242, p = .629) or Sex (F = .024, p = .878), and no interaction (F = .450, p = .512).

For this reason, the data were collapsed across Sex for subsequent analyses. In the case of Fixation Count on images of all take-home key rings, the data were collapsed across both Sex and Condition.

There was no significant correlation between Age at first visit and Questionnaire Score (*Pearson's* r = .074, p = .758). Collapsing across Experiments 1, 2, and 3 showed a significant positive correlation between Age and Questionnaire Score (*Pearson's* r = .245, p = .030). This is in accordance with the hypothesis of Needham et al. (2006) that experience with key ring exemplars increases with age, although this increase appears to be mild and does not always appear in small samples. To observe a significant effect of age, a larger sample would be required.

Primary Analyses

I predicted that infants would fixate about an equal number of times overall regardless of condition. An independent samples t-test on the effect of Condition on infants' Fixation Count on the Final Keys Location during all test trials supported this prediction by revealing no effect of Condition ($t = 1.201$, $p = .245$).

My next analyses dealt directly with my hypotheses. An independent samples t-test on Condition and Fixation Count on the Final Keys Location AOI in all test events yielded a significant effect of Condition ($t = -2.164$, $p = .044$), revealing that infants who viewed the Move-together event fixated significantly more often on this AOI than did infants in the Move-apart event ($M = 6.60$, $SD = 4.274$ and $M = 3.40$, $SD = 1.897$, respectively). This is consistent with the findings from Experiments 1 and 2, suggesting that category knowledge was not applied.

Next, I conducted an independent samples t-test on the effect of Condition on infants' Fixation Count on the Final Keys Location AOI during the movement only portion of the test trials, revealing no significant effect ($t = 1.439$, $p = .167$). However, infants in the Move-apart condition fixated more often on average ($M = 1.10$, $SD = 1.197$) on the Final Keys Location AOI than did the infants in the Move-together condition, as can be seen in Figure 15 ($M = .40$, $SD = .966$).

Note also that infants in the Move-apart condition in Experiment 3 fixated more often on average ($M = 1.10$, $SD = 1.197$) than did infants in the Move-apart condition in

Experiment 2 (M = .25, SD = .463). It is worth noting that although only two infants fixated on the Final Keys Location AOI during the movement in the Move-apart condition in Experiment 2, this number jumped to six infants in Experiment 3. As had been the case in Experiment 2, there were no apparent consistencies in the age, sex, or prior experience of the infants who fixated on the Final Keys Location AOI during the movement in the Move-apart condition in Experiment 3: four were female, two male, infants were between the ages of 7 months, 17 days and 8 months, 23 days, and prior experience scores ranged from 24.19% to 66.13%.

Somewhat surprisingly, only 2 infants in the Move-together condition fixated on the Final Keys Location AOI during the movement. Both were female between 6.5 months and 7.5 months, with moderate questionnaire scores. A closer look at the AOIs fixated upon during the movement by infants in the Move-together condition revealed that the majority of infants fixated primarily on the ring as it shifted from the Original Ring Location AOI to the Ring Move Location AOI, and finally to the Final Ring Location AOI. To a slightly lesser extent, this wealth of fixations on the ring during the movement was also true of the infants in the Move-apart condition. This is not surprising in light of the manner in which infants saw the keys presented by the experimenter and their parents in the play sessions: in both cases, the adult grasped the key ring by the ring and shook it, thus drawing attention to the ring as the controller of the keys. For more details on Move-together and Move-apart infants' fixation behavior during the movement event, see Figure 16.

My final analysis on the experimental videos data explored the effect of Condition on Fixation Count on the Final Keys Location AOI following the completion of the movement. An independent samples t-test revealed a significant effect of Condition (t = -4.531, p = .001) such that infants in the Move-together condition fixated a greater number of times on average (M = 3.80, SD = 2.348) on the Final Keys Location AOI following the completion of the movement than did infants in the Move-apart condition (M = .30, SD = .675), as can be seen in Figure 17. As was the case in Experiment 2, all infants in the Move-together condition in Experiment 3 fixated on the keys when they appeared in the Final Keys Location AOI. Only two infants in the Move-apart condition in Experiment 3 fixated on the Final Keys Location AOI following the completion of the movement. By comparing infants' fixations on all the AOIs following the completion of the movement, I found that these infants as well as the other infants in the Move-apart condition fixated primarily on the Final Ring Position AOI. As stated before, this is unsurprising considering the continuous highlighting of the ring that occurred in the play sessions. For more details on Move-together and Move-apart infants' fixation behavior following the movement event, see Figure 18.

The purpose of this experiment was to remove any doubt that all infants participating in the study had enough experience with key ring objects to have formed a key ring category prior to viewing the experimental stimuli, and then to examine if infants would show the predicted fixation patterns that would indicate the application of this category knowledge. Taken together, the results on the experimental videos indicate that infants in Experiment 3, in comparison to Experiment 2, were somewhat better at applying categorical knowledge to the scenes depicted on screen, but that this application was not consistent enough to warrant a significant difference between infants in the Move-apart and the Move-together conditions. Once again, I have failed to replicate the results of Needham et al.'s (2006) Experiment 1. It appears that the existence of category knowledge alone is not the only factor causing these results, and that there are likely other issues related to the use of 2-dimensional video or image stimuli instead of 3-dimensional live stimuli at work.

I then examined infants' fixation behaviors on the static images of key rings via a repeated measures t-test. This analysis revealed a significant increase in Fixation Count on the key ring images (M = 17.100, SD = 18.843, t = 4.059, DF = 19, p = .001) from the first visit (M = 21.70, SD = 8.945) to the second visit (M = 38.80, SD = 16.002).

In light of this data, the first hypothesis I formed in regards to infants' fixation behaviors on the static images of key rings, that is, that Fixation Count would increase from the first to second visit, is supported. As predicted, infants did indeed increase in number of fixations on the images of key rings from the first to the second visit, suggesting that infants did not habituate to these images between their first and second visits to the lab. The cause of this is not entirely clear: it may be that infants' failure to habituate was a reaction to the change in medium between their hands-on experience with key rings and the passive viewing of the same key rings on a screen: the key rings infants had interacted with during the two-week play period were 3-dimensional, graspable objects, whereas the static images of key rings onscreen were 2-dimensional, impossible-to-grasp objects. Or, perhaps infants simply became more interested in key ring objects in any medium following extensive experience with them. It may also be that infants' attention to the images onscreen increased following the previous exposure to some of the same stimuli, an explanation that is consistent with the findings of Barr, Zack, Muentener, and Garcia (2008) with 12- and 18-month-old infants, who looked longer at a particular infant video if they had viewed it before.

Finally, I examined the possibility of preferences for one key ring exemplar over the others, as expressed by unequal Fixation Count on a given key ring image. Using the data collected during the **first** visit to the lab, I investigated the effects of Key Ring (i.e., Key Ring 1, Key Ring 2, Key Ring 3, and Key Ring 4) on Fixation Count via ANOVA. There was no significant effect of Key Ring (F = .031, p = .863; F = .034, p = .855; F = .432, p = .520; F = .989, p = .333 for Key Rings 1, 2, 3, and 4, respectively). Then, using the data collected during the **second** visit to the lab, I investigated the effects of Key Ring (i.e., Key Rings 1 through 4 and the Experimental Key Ring) on Fixation Count via ANOVA. This analysis yielded a no significant effect of Key Ring (F = .996, p = .332; F = 1.196, p = .289; F = .108, p = .746; F = .521, p = .480; F = .754, p = .397 for Key Rings 1, 2, 3, 4, and Experimental, respectively). These analyses indicate that infants had no fixation preference for any particular key ring exemplar over the others, nor did they appear to differentiate between the different images.

These last findings are the converse of my prediction: infants did not appear to recognize the Experimental Key Ring as novel compared to the familiar take-home key rings, and therefore did not fixate more often on the Experimental rather than take-home Key Rings. It appears that infants may be able to recognize various objects as belonging within the key ring category following extensive experience with that category, yet they may not differentiate between specific exemplars from that category. This interpretation is supported by previous research on infant categorization indicating that 6-month-old infants differentiate between exemplars when exemplars are labeled individually (i.e., with an individualized term for each exemplar) during training, but fail to differentiate between specific exemplars when exemplars are labeled categorically (i.e., with an identical generic term for all exemplars) during training (Scott & Monesson, 2010).

CHAPTER V

GENERAL DISCUSSION

A large body of research indicates that infants come to categorize objects prior to developing language, and are capable of using such category knowledge to perceive complex scenes in a top-down manner (Kovack-Lesh et al., 2008; Needham et al., 2006; Scott & Monesson, 2010; Scott et al., 2007). However, recent developments in both research methodology used with infants and the day-to-day environment of infants outside the lab have brought up new questions about the generalizability of earlier studies' results and conclusions. Previously, it appeared that there were few differences in infants understanding of video and images versus direct, live experience, and that any differences in infants' responses to 2-dimensional versus 3-dimensional contexts emerged later. However, recent research suggests that infants, even those under 12 months of age, respond differently to stimuli on video and in static images as they do to the same stimuli in live contexts. The current experiments were undertaken in order to examine whether the results obtained with a previous study on infant categorization (i.e., Needham et al., 2006) would be replicated when the stimuli were transferred from a live, 3-dimensional context to two different 2-dimensional contexts (i.e., static images in Experiment 1 and dynamic videos in Experiments 2 and 3), and if infants' prior experience with the target category of objects had been directly manipulated (as in Experiment 3) or not (as in Experiments 1 and 2).

In my first experiment, I used an eye-tracking device to display static images depicting a hand moving the ring of a partially occluded key ring object such that either the keys moved with the ring (Move-together condition) but were unnaturally clumped together, or the keys failed to move with the ring at all (Move-apart condition). Both of these events would violate infants' expectations about key ring objects if infants were applying a category of key ring objects, and therefore infants using category knowledge should have fixated on the Final Keys Location AOI equally in both conditions. Yet, all infants regardless of age or prior experience with key ring objects only consistently fixated on the Final Keys Location AOI in the Move-together condition, indicating that they were not employing category knowledge but rather relied on differences in shape, color, and texture to perceive the display as consisting of separate pieces. Despite this lack of category knowledge employment, the results of Experiment 1 indicate that these infants may have been sensitive to more basic rules of object behavior, such as the independent motion of unconnected objects and the necessity of support to prevent objects in midair from falling. These results were likely due to a combination of factors: the unnatural movement of the keys in the Move-together event, the difficulty of adequately conveying movement via static images, as well as the inconsistent prior experience with key rings reported by parents in this study versus Needham et al. (2006).

In the second experiment, I altered the stimuli to resolve the first of these issues: I displayed dynamic videos depicting a hand moving the ring of a partially occluded key ring object such that either the keys moved naturally with the ring (Move-together condition), or the keys failed to move with the ring (Move-apart condition) on an eye-tracking device. I predicted that infants utilizing category knowledge to perceive the display would on the Final Keys Location AOI significantly more often during the movement in the Move-apart condition than they would in the Move-together condition, and significantly more often on that same AOI following the completion of the movement in the Move-together condition than in the Move-apart condition. The latter but not the former part of the hypothesis was supported by the results: infants fixated significantly longer on this location in the Move-together condition than in the Move-apart condition **after** the keys had appeared in the Final Keys Location AOI, but not **before** the keys appeared there as if expecting their appearance. Further analyses revealed a weak correlation between age and experience as predicted by Needham et al. (2006), but no correlation between age and experience and fixation behavior during the movement events. From these results, I concluded that infants in this experiment were not employing category knowledge of key ring objects to the events depicted onscreen, and that perhaps the suspected problems with prior experience with key ring objects mentioned in Experiment 1 were more influential than I had initially suspected.

In the third and final experiment, I directly manipulated infants' experience with key ring objects for two weeks prior to testing their application of category knowledge with either the Move-apart event or the Move-together event. In addition to viewing the same dynamic videos used in Experiment 2, infants in Experiment 3 viewed static images of the key rings they experienced at home during their first lab visit prior to at-home experience, and during their second lab visit following at-home experience and testing with either the Move-apart event or the Move-together event. My hypotheses about the experimental videos were the same as those of Experiment 2. In terms of significance, the results were the same as those of Experiment 2. Yet, a closer analysis showed that infants in the Move-apart condition of Experiment 3 were more likely to show the predicted pattern of fixations associated with category knowledge, albeit inconsistently, than were infants in the same condition in Experiment 2.

Taken together, the results of Experiments 1, 2, and 3 indicate that 7- to 9-month-old infants struggle to apply category knowledge of objects to events they see in 2-dimensional images and on video, even if they have extensive 3-dimensional experience with exemplars from that category. In short, there appears to be a video deficit at work that comes into play when infants are called upon to connect their experiences with objects in the 3-dimensional world to 2-dimensional representations of those objects. This is not an unheard of phenomena with this age group: other studies have shown that 6- and 10-month-old infants interpret events involving 3-dimensional objects in a meaningful way (i.e., perceiving an object as either a "helper" or a "hinderer" to another object in a sequence of events and then preferentially selecting the "helper" object), but do not show the same response to identical events and objects in 2-dimensional displays until 12 months of age, suggesting an issue of context rather than content (Hamlin, Wynn, & Bloom, 2007; Kuhlmeier, Wynn, & Bloom, 2003). There are multiple factors that could be at work in producing this effect, although the results of the three studies presented here do not fully resolve the question of why this video deficit occurred, nor do they point to a single interpretation from any of the several dominant theories concerning the video deficit.

One possible challenge to infants' category application in these studies that did not exist in the original Needham et al. (2006) studies is the dearth of and degraded nature of perceptual cues in 2-dimensional versus 3-dimensional experience. Nine-month-old infants appear to be sensitive to the quality of a 2-dimensional depiction of a

3-dimensional object, for instance displaying more manual exploration of realistic rather than unrealistic 2-dimensional representations of objects (Pierroutsakos & DeLoache, 2007). Compared to the 3-dimensional key ring experience reported in the questionnaires for infants in all three experiments, or the enriched experience provided in Experiment 3, the key ring in the experimental video was dark, distant, and low-contrast, besides not providing the usual cues of depth and motion available in 3-dimensional experience (e.g., motion parallax, binocular disparity, etc.). The comparatively low quality 2-dimensional representation of the key ring object on video, to say nothing of the impossibility of exploring its physical affordances, may have hampered infants from successfully generalizing their category knowledge of key ring objects to the experimental key ring.

However, this explanation is not fully satisfying in light of the evidence, albeit inconsistent, that infants in Experiment 3 may have been applying category knowledge to the events onscreen. It has been established that infants several months younger than the participants in these studies perceive the correspondence between a 3-dimensional object and a 2-dimensional depiction of it, and that 9-month-old infants discriminate between 3-dimensional objects and 2-dimensional objects (DeLoache et al., 1998; DeLoache et al., 1979; Field, 1976; Rose, 1977). It is therefore unlikely that infants in Experiments 1, 2, and 3 failed to recognize a key ring when they saw one onscreen or failed to understand these objects' 2-dimensionality.

Once again, we are left with the question of why infants did not apply their category knowledge to the objects onscreen if category knowledge is present and the objects onscreen are familiar. The dual representation explanation of the video deficit offers a possible explanation: recognizing familiar objects onscreen and realizing that they are 2-dimensional and not 3-dimensional may not be enough. Infants may still struggle to understand the implications of 2-dimensionality versus 3-dimensionality for object behavior, and be uncertain as to whether 2-dimensional objects behave in the same way as 3-dimensional objects or not. This interpretation fits well with past research conducted on 9-month-old infants' manual exploration of pictured and video objects, which suggests that infants are unclear as to the affordances of 2-dimensional objects despite their ready discrimination between 2-dimensional and 3-dimensional objects (DeLoache et al., 1998; Pierroutsakos & Troseth, 2003; Pierroutsakos, 1999).

Limitations and Future Directions

Of course, as stated before these three experiments alone do not provide adequate support for this interpretation. In future, in order to understand the cause of the video deficit in this case I will attempt to circumvent it. Several factors have been used in other studies to decrease the video deficit, and while some are not pertinent to this age group (e.g., verbal explanations) others such as repetition and prior experience particularly may be quite helpful (for a recent summary of factors that ameliorate the video deficit, see Barr, 2010). Future studies in this line of inquiry will focus on providing infants not with 3-dimensional experience with the target category, but 2-dimensional experience alone or better yet a combination of 3-dimensional and 2-dimensional experience that will highlight the correspondence between objects in the two contexts.

In future studies, I will collect information on infants' prior experience with images or videos, as this may be a component in infants' ability to generalize a 3-dimensional category to 2-dimensional exemplars. None of the experiments presented herein made a point of collecting this information from parents, although such data was collected from parents of several infants in Experiment 2 coincidentally. Interestingly, the infant in the Move-apart condition who fixated expectantly in the Final Keys Location AOI during **and** following the movement event had a great deal of prior experience with video (approximately 6-10 hours of video exposure a week), suggesting that perhaps such exposure could indeed be a factor in enabling transfer between 3-dimensional and 2-dimensional experience.

Further, the variety of 2-dimensional media available to parents and infants makes it necessary to examine not only the amount, but also the type of video and image exposure infants participating in these studies receive. Extensive experience with static images in picture frames is not the same as experience with images that can be "flipped" through rapidly at the touch of a finger on a smart phone, nor is prerecorded video experience the same as contingent live video experience: each in its own way may support or undermine infants' ability to transfer knowledge of objects and events in one medium to the other.

Conclusion

In a series of three experiments adapted from a previous study conducted by Needham et al. (2006), I demonstrated that 7- to 9-month-old infants fail to use category knowledge of 3-dimensional objects to guide their perceptions of 2-dimensional objects in televised images and on video, indicating the presence of a video deficit. Although improving the quality of the 2-dimensional context (i.e., using dynamic videos rather than static images to portray movement) and enriching infants' experience with 3-dimensional exemplars from the target category appeared to marginally improve infants' application of category knowledge to a 2-dimensional exemplar, these were not significant improvements. Although these experiments alone do not provide a definitive explanation of the source of this video deficit, it is likely that a combination of the dearth and degradation of perceptual cues in 2-dimensional contexts compared to 3-dimensional contexts, and more importantly infants' uncertainty about the properties of 2-dimensional objects in comparison to 3-dimensional objects. Future studies will focus on testing these possible explanations.

APPENDIX A: FIGURES

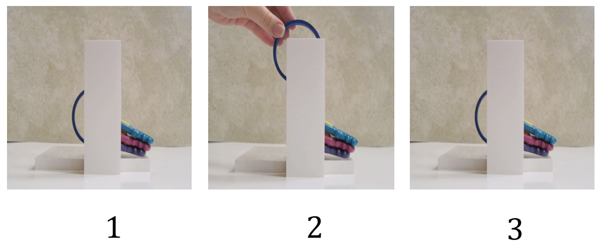


Figure 1. Move-apart event in Experiment 1

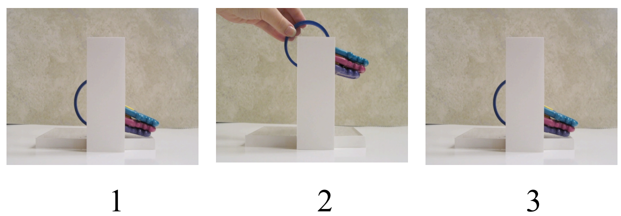
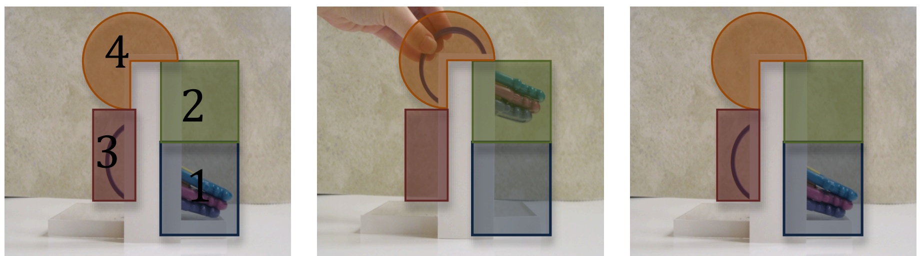


Figure 2. Move-together event in Experiment 1

1 2 3

In Move-apart



1 2 3

In Move-together

Figure 3. Areas of Interest (AOIs) in Experiment 1

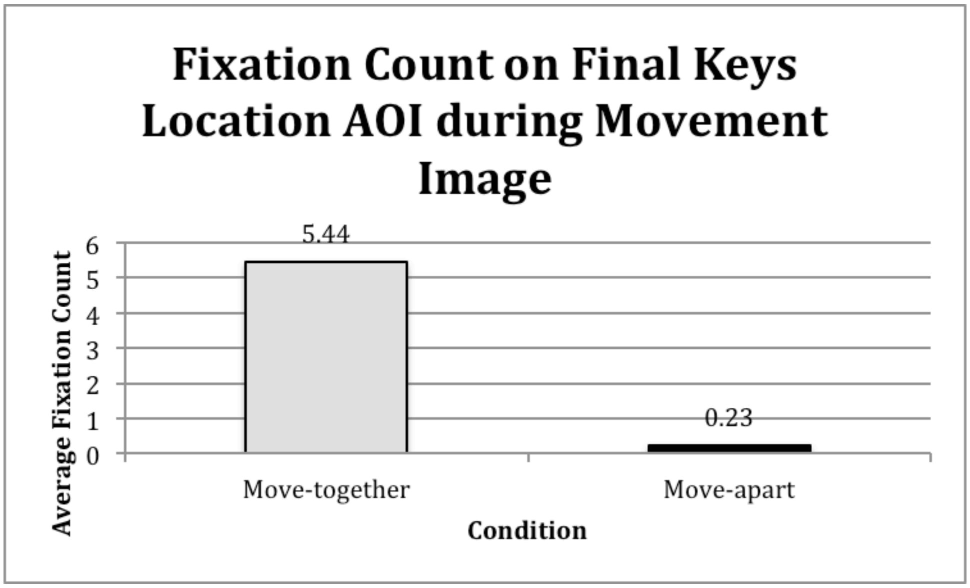


Figure 4. Fixation Count on Final Keys Location AOI during Movement Image in Experiment 1

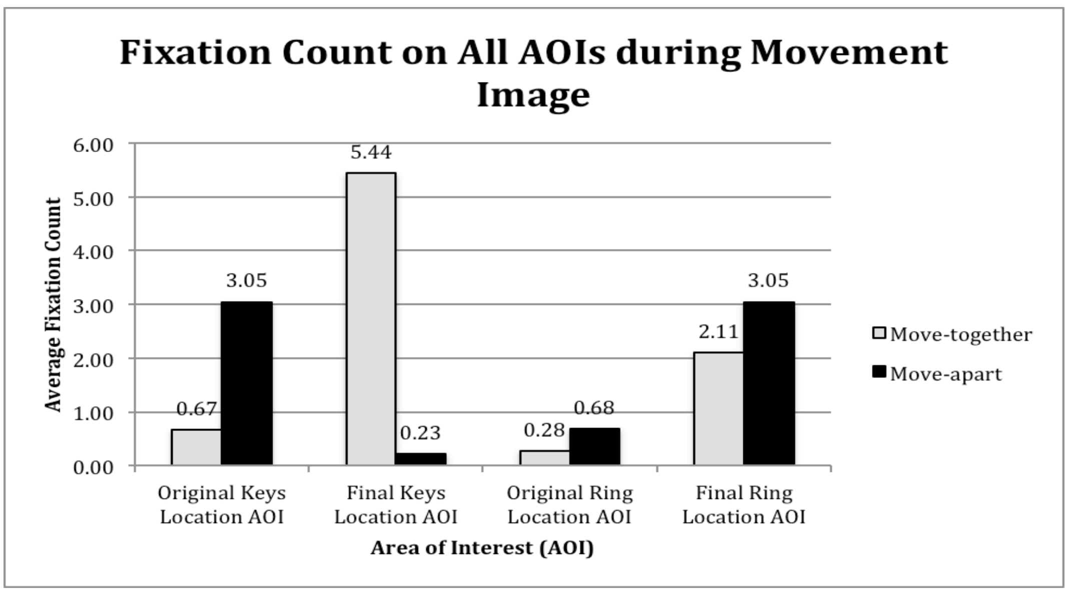


Figure 5. Fixation Count on All AOIs during Movement Image in Experiment 1

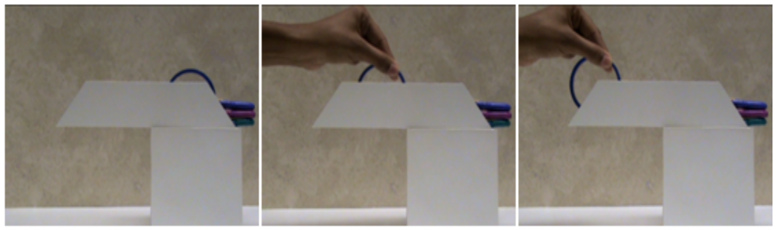


Figure 6. Move-apart event in Experiments 2 & 3

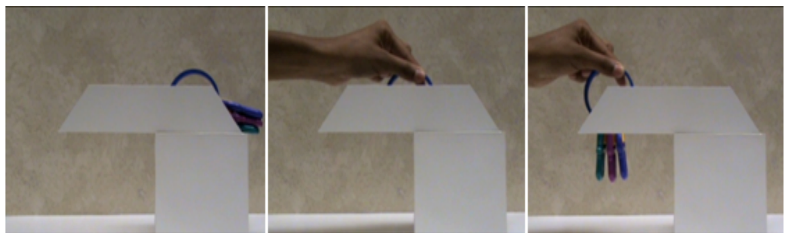
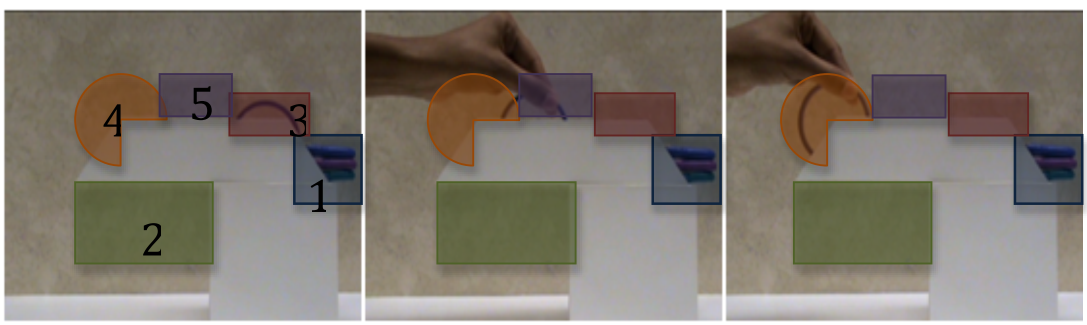
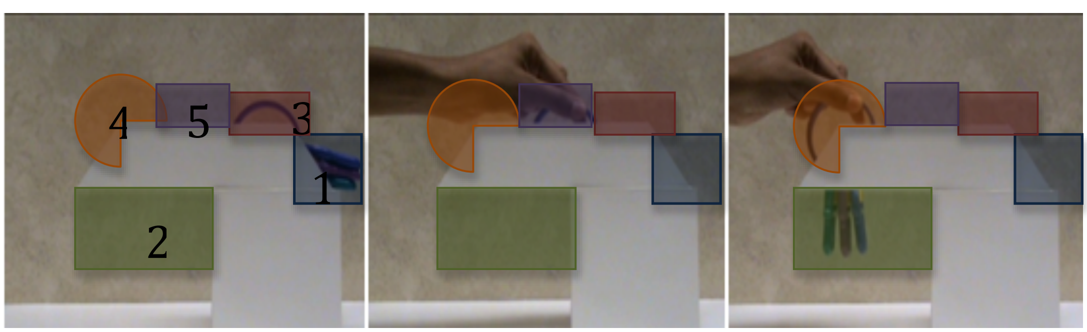


Figure 7. Move-together event in Experiments 2 & 3



In Move-apart



In Move-together

Figure 8. Areas of Interest (AOIs) in Experiments 2 & 3

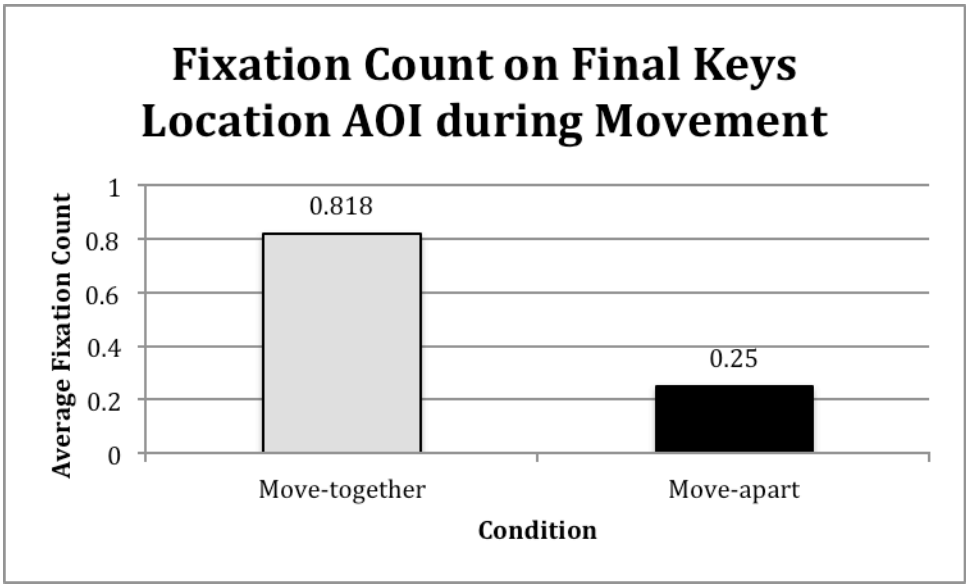


Figure 9. Fixation Count on Final Keys Location AOI during Movement in Experiment 2

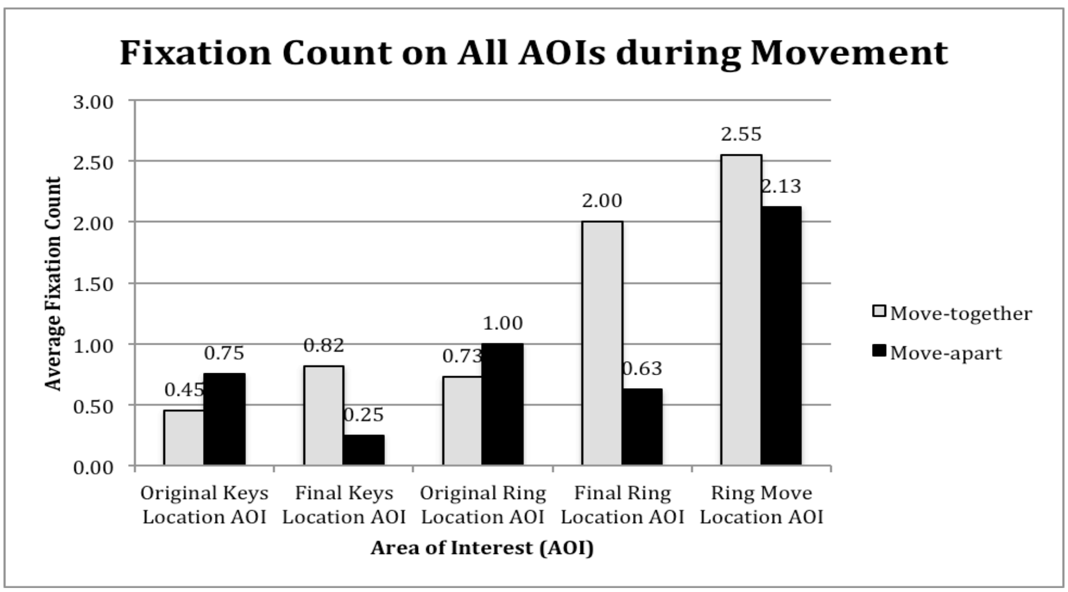


Figure 10. Fixation Count on All AOIs during Movement in Experiment 2

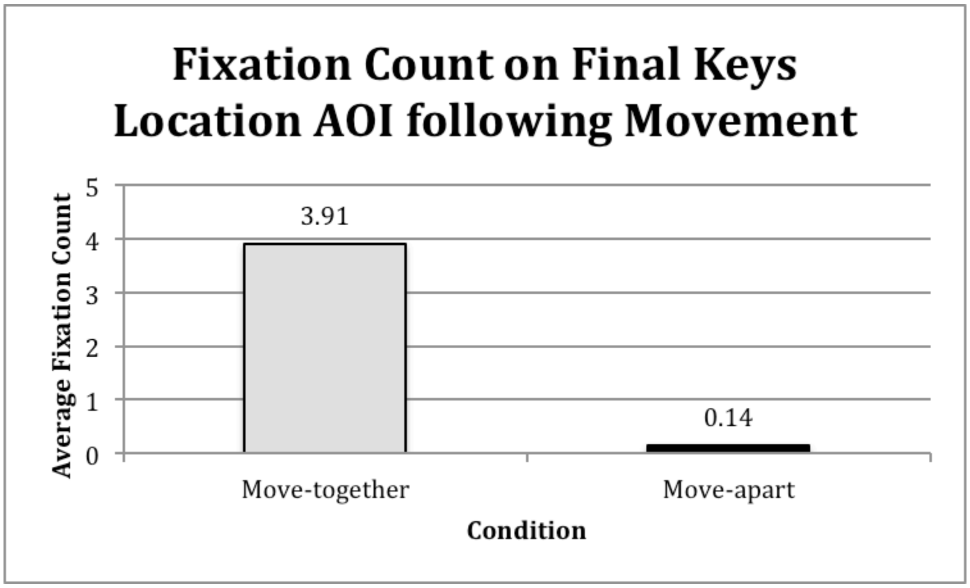


Figure 11. Fixation Count on Final Keys Location AOI following Movement in Experiment 2

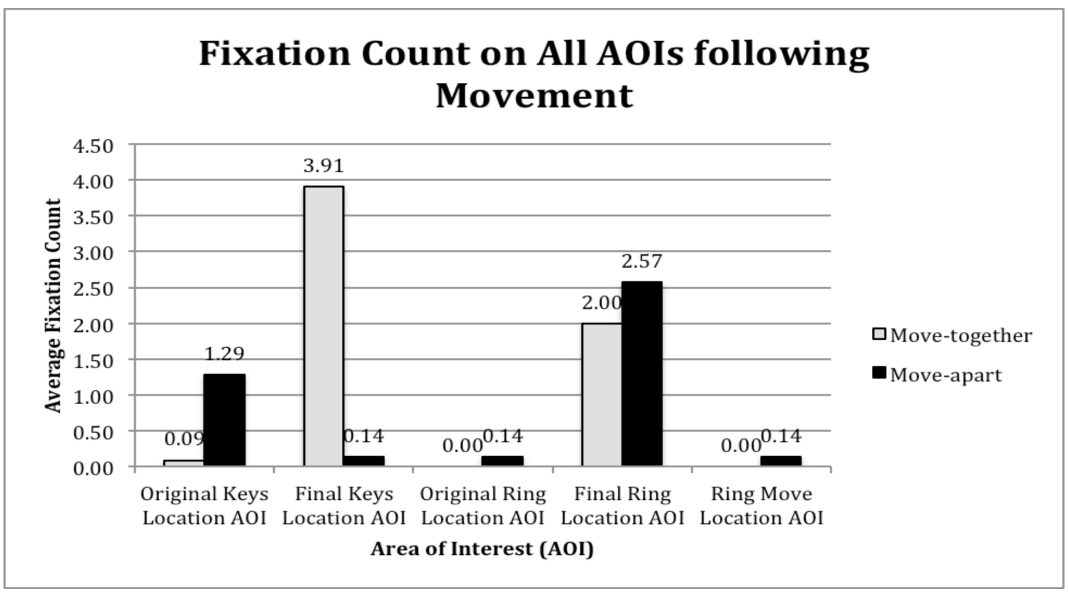


Figure 12. Fixation Count on All AOIs following Movement in Experiment 2

In Visit 1

In Visit 2

Figure 13. Static Images of Key Ring Toys

Figure 14. Areas of Interest (AOIs) on Static Images of Key Ring Toys

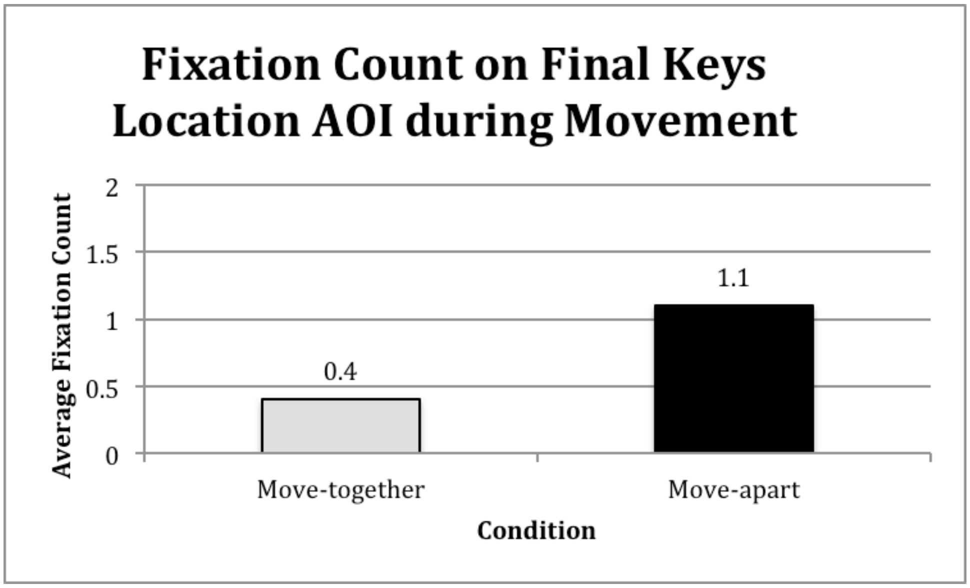


Figure 15. Fixation Count on Final Keys Location AOI during Movement in Experiment 3

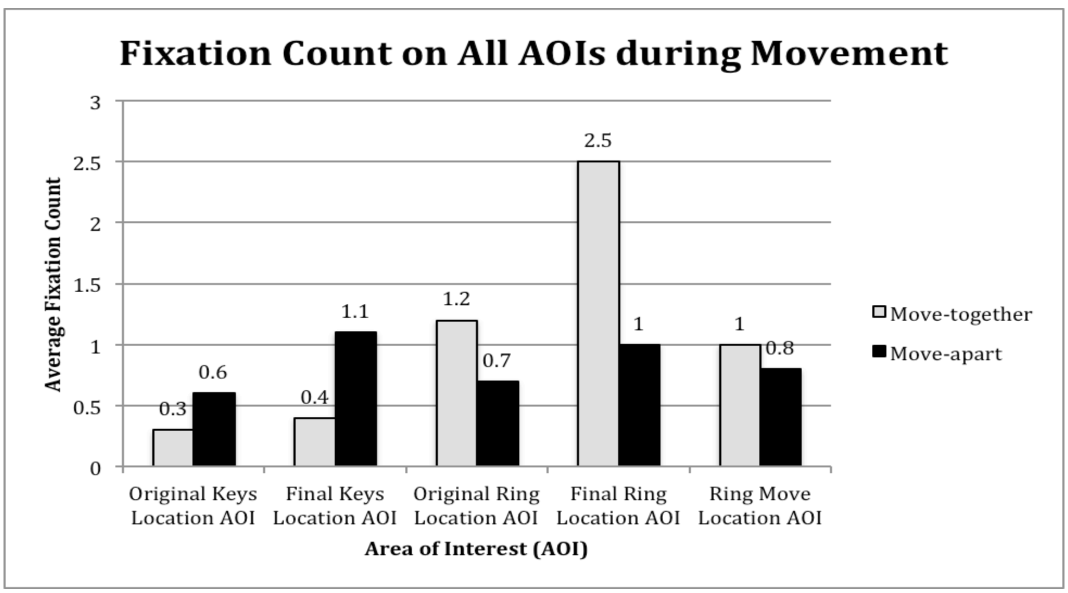


Figure 16. Fixation Count on All AOIs during Movement in Experiment 3

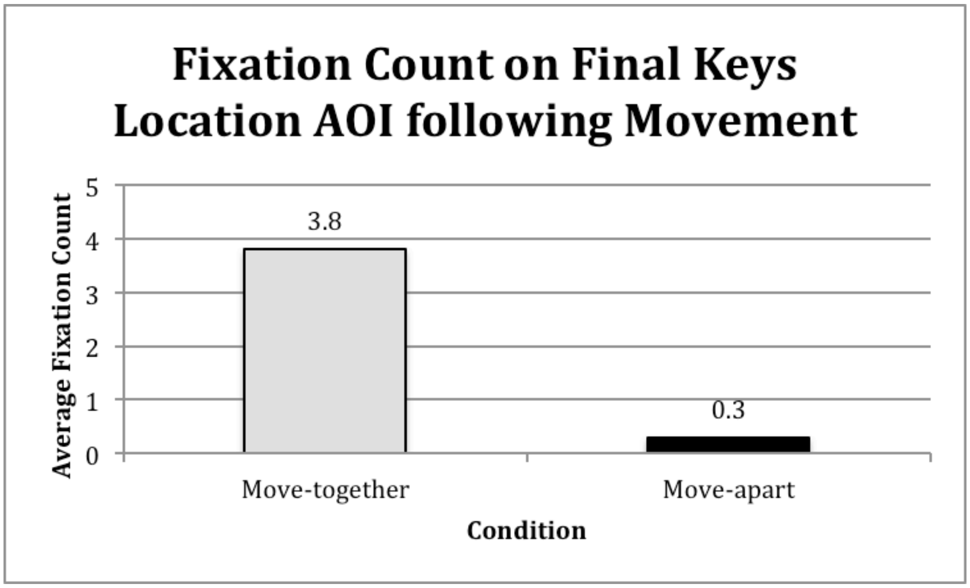


Figure 17. Fixation Count on Final Keys Location AOI following Movement in Experiment 3

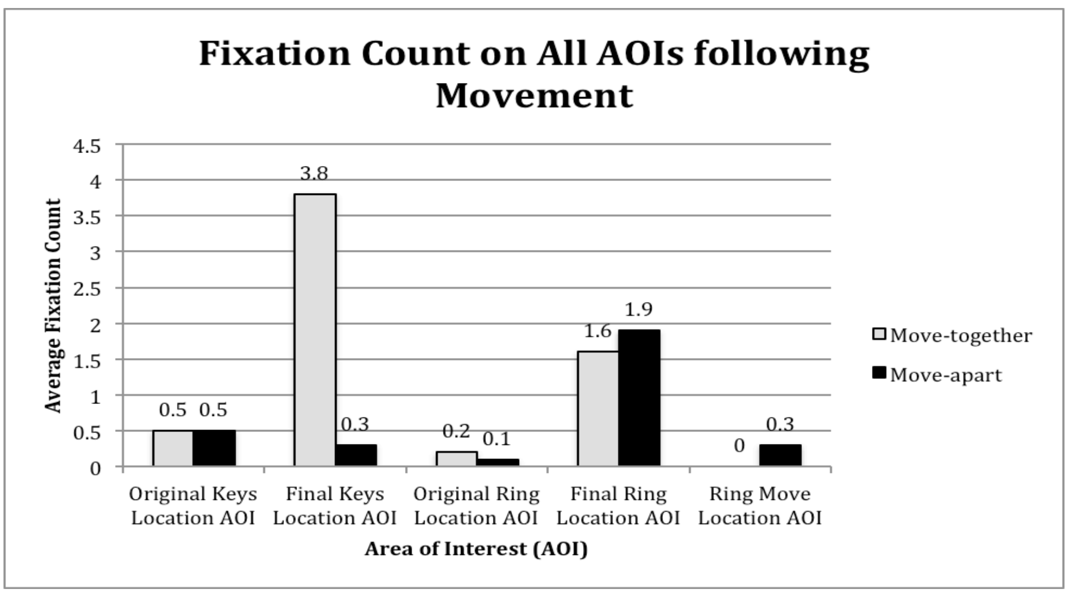


Figure 18. Fixation Count on All AOIs following Movement in Experiment 3

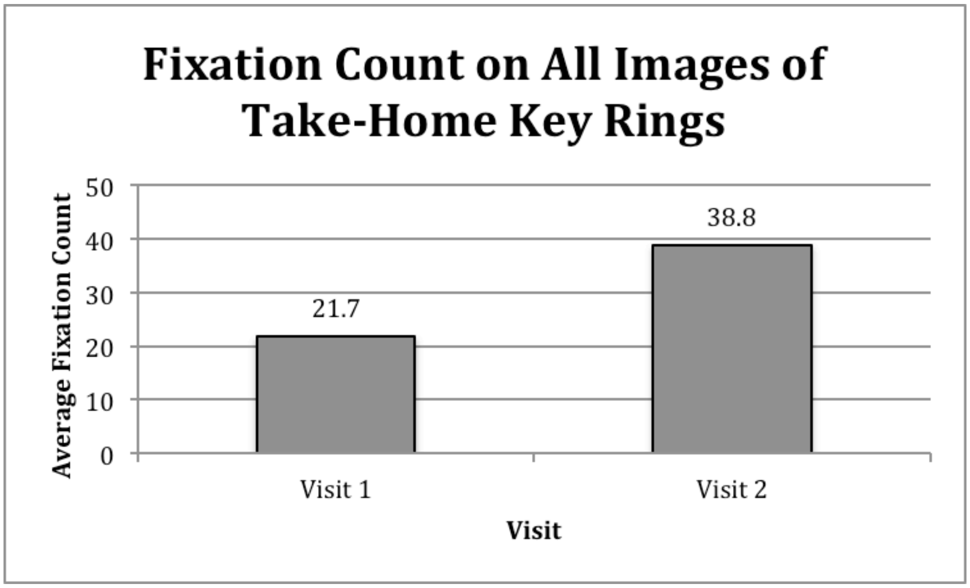


Figure 19. Fixation Count on Static Images of Take-Home Key Rings in Experiment 3

REFERENCES

Anderson, D. R., Lorch, E. P., Field, D. E., & Sanders, J. (1981). The effect of television program comprehensibility on preschool children's visual attention to television. *Child Development, 52,* 151-157.

Anderson, D. R., & Pempek, T. A. (2005). Television and Very Young Children. *American Behavioral Scientist*, *48*(5), 505–522. doi:10.1177/0002764204271506

Aslin, R. N. (2007). What's in a look? *Developmental science*, *10*(1), 48–53. doi:10.1111/j.1467-7687.2007.00563.x

Baillargeon, R., & Hanko-Summers, S. (1990). Is the top object adequately supported by the bottom object? young infants' understanding of support relations. *Cognitive Development*, *5*(1), 29–53. doi:10.1016/0885-2014(90)90011-H

Baillargeon, R., Needham, A., & Devos, J. (1992). Intuitions about Support. *Early Development and Parenting*, *1*(2), 69–78.

Baldwin, D. A., Baird, J. A., Saylor, M. M., & Clark, M. A. (2001). Infants Parse Dynamic Action. *Child Development*, *72*(3), 708–717. doi:10.1111/1467-8624.00310

Barnat, S. B., Klein, P. J., & Meltzoff, A. N. (1996). Deferred Imitation Across Changes in Context and Obiect : Memory and Generalization in 14-Month-OId Infants. *Infant Behavior and Development*, *19*, 241–251.

Barr, R., & Hayne, H. (1999). Developmental changes in imitation from television during infancy. *Child development*, *70*(5), 1067–81. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/10546335

Barr, R. (2010). Transfer of learning between 2D and 3D sources during infancy: Informing theory and practice. *Developmental review : DR*, *30*(2), 128–154. doi:10.1016/j.dr.2010.03.001

Barr, R., Muentener, P., & Garcia, A. (2007). Age-related changes in deferred imitation from television by 6- to 18-month-olds. *Developmental science*, *10*(6), 910–21. doi:10.1111/j.1467-7687.2007.00641.x

Barr, R., Zack, E., Garcia, A., & Muentener, P. (2008). Infants ' Attention and Responsiveness to Television Increases With Prior Exposure and Parental Interaction. *Infancy*, *13*(1), 30–56.

Barrera, M. E., & Maurer, D. (1981). Recognition of Mother ' s Photographed Face Infant by the Three-Month-Old. *Child development*, *52*(2), 714–716.

Borovsky, D., & Rovee-Collier, C. (1990). Contextual constraints on memory retrieval at six months. *Child development*, *61*(5), 1569–83. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/2245747

Brito, N., Barr, R., McIntyre, P., & Simcock, G. (2012). Long-term transfer of learning from books and video during toddlerhood. *Journal of experimental child psychology*, *111*(1), 108–19. doi:10.1016/j.jecp.2011.08.004

Christakis, D. (2009). The effects of infant media usage: what do we know and what should we learn? *Acta paediatrica (Oslo, Norway : 1992)*, *98*(1), 8–16. doi:10.1111/j.1651-2227.2008.01027.x

Csibra, G., Gergely, G., Biro, S., Koos, O., & Brockbank, M. (1999). Goal attribution without agency cues : the perception of ` pure reason ' in infancy. *Cognition*, *72*, 237–267.

DeLoache, J. S., & Chiong, C. (2009). Babies and Baby Media. *American Behavioral Scientist*, *52*(8), 1115–1135. doi:10.1177/0002764209331537

Deloache, J. S. (2004). Becoming symbol-minded. *Trends in cognitive sciences*, *8*(2), 66–70. doi:10.1016/j.tics.2003.12.004

DeLoache, J. S., Chiong, C., Sherman, K., Islam, N., Vanderborght, M., Troseth, G. L., Strouse, G. a, et al. (2010). Do babies learn from baby media? *Psychological science*, *21*(11), 1570–4. doi:10.1177/0956797610384145

DeLoache, J. S., Pierroutsakos, S. L., Uttal, D. H., Rosengren, K. S., & Gottlieb, A. (1998). Grasping the nature of pictures. *Psychological Science, 9*, 205–210.

DeLoache, J. S., Strauss, M.S., & Maynard, J. (1979). Picture perception in infancy. *Infant Behavior & Development, 2*, 77–89.

Deocampo, J. A., & Hudson, J. A. (2009). When Seeing is Not Believing : Two-Year-Olds ' Use of Video Representations to Find a Hidden Toy. *Journal of Cognition and Development*, *6*(November 2012), 37–41.

DeoCampo, J. A. (2003). *A new paradigm for testing dual representational understanding with different representational demands.* (unpublished doctoral dissertation). Rutgers, The State University of New Jersey, New Brunswick, New Jersey.

Dirks, J., & Gibson, E. (1977). Infants' perception of similarity between live people and their photographs. Dueker, G., & Needham, A. (2005). Infants' object category formation and use: Real-world context effects on category use in object processing. *Visual Cognition*, *12*(6), 1177–1198. doi:10.1080/13506280444000706

Dueker, G. L., Modi, A., & Needham, A. (2003). 4.5-Month-Old Infants' Learning, Retention and Use of Object Boundary Information. *Infant Behavior and Development*, *26*(4), 588–605. doi:10.1016/j.infbeh.2003.05.002

Fidler, A. E., Zack, E., & Barr, R. (2010). Television Viewing Patterns in 6- to 18-Month-Olds: The Role of Caregiver-Infant Interactional Quality. *Infancy*, *15*(2), 176–196. doi:10.1111/j.1532-7078.2009.00013.x

Field, J. (1976). Relation of young infants' reaching behavior to stimulus distance and solidity. *Developmental Psychology*, *12*(5), 444–448. doi:10.1037//0012-1649.12.5.444

Gergely, G., Nadasdy, Z., Csibra, G., & Bfr, S. (1995). Taking the intentional stance at 12 months of age, *0277*(95).

Goldstone, R. L. (1998). Perceptual learning. *Annual review of psychology*, *49*, 585–612. doi:10.1146/annurev.psych.49.1.585

Hayne, H., Boniface, J., & Barr, R. (2000). The development of declarative memory in human infants: Age-related changes in deffered imitation. *Behavioral Neuroscience*, *114*(1), 77–83.

Hayne, H., Herbert, J., & Simcock, G. (2003). Imitation from television by 24- and 30-month-olds. *Developmental Science*, *6*(3), 254–261. doi:10.1111/1467-7687.00281

Hochberg, J., & Brooks, V. (1962). Pictorial Recognition as an Unlearned Ability: A study of one child's performance. *The American Journal of Psychology*, *75*(4), 624–628.

Johnson, S. P., & Aslin, R. N. (1996). Perception of object unity in young infants: The roles of motion, depth, and orientation. *Cognitive Development*, *11*(2), 161–180. doi:10.1016/S0885-2014(96)90001-5

Johnson, S. P., Bremner, J. G., Slater, A. M., Mason, U. C., & Foster, K. (2002). Young Infants ' Perception of Unity and Form in Occlusion Displays. *Journal of Experimental Child Psychology*, *81*, 358–374. doi:10.1006/jecp.2002.2657

Kellman, P. J. (1984). Perception of three-dimensional form by human infants. *Perception & psychophysics*, *36*(4), 353–8. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/6522232

Kellman, P. J., & Spelke, E. S. (1983). Perception of partly occluded objects in infancy. *Cognitive psychology*, *15*(4), 483–524. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/6641127

Kovack-Lesh, K. A., Horst, J. S., & Oakes, M. (2008). The Cat is out of the Bag : The Joint Influence of Previous Experience and Looking Behavior on Infant Categorization. *Infancy*, *13*(4), 37–41.

Kuhlmeier, V., Wynn, K., & Bloom, P. (2003). Attribution of dispositional states by 12-month-olds. *Psychological Science, 14*, 402–408.

Mandler, J. M., & McDonough, L. (1996). Drinking and driving don't mix: inductive generalization in infancy. *Cognition*, *59*(3), 307–35. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/8706380

Mandler, J. M., & McDonough, L. (1998). Studies in inductive inference in infancy. *Cognitive psychology*, *37*(1), 60–96. doi:10.1006/cogp.1998.0691

Mandler, J. M. (2004). Thought before language. *Trends in cognitive sciences*, *8*(11), 508–13. doi:10.1016/j.tics.2004.09.004

Meltzoff, A. N. (1988). Imitation of Televised Models by Infants. *Child development*, *59*(5), 1221–1229.

Needham, A., & Baillargeon, R. (1993). Intuitions about support in 4.5-month-old infants. *Cognition*, *47*, 121–148.

Needham, A., & Baillargeon, R. (1998). Effects of prior experience on 4.5-month-old infants' object segregation. *Infant Behavior and Development*, *21*(1).

Needham, A., & Modi, A. (2000). In *Advances in child development and behavior, Vol. 27*, by Needham, A., Modi, A., 99-133. San Diego, CA, US:Academic Press, 2000.

Needham, A. (1998). Infants' use of featural information in the segregation of stationary objects. *Infant Behavior and Development*, *21*(1), 47–75.

Needham, A. (1999). The role of shape in 4-month-old infants' object segregation. *Infant Behavior and Development*, *22*(2), 161–178. doi:10.1016/S0163-6383(99)00008-9

Needham, A. (2000). Improvements in Object Exploration Skills May Facilitate the Development of Object Segregation in Early Infancy. *Journal of Cognition and Development*, *1*(2), 131–156. doi:10.1207/S15327647JCD010201

Needham, A. (2001). Object recognition and object segregation in 4.5-month-old infants. *Journal of experimental child psychology*, *78*(1), 3–22. doi:10.1006/jecp.2000.2598

Needham, A., Cantlon, J. F., & Ormsbee Holley, S. M. (2006). Infants' use of category knowledge and object attributes when segregating objects at 8.5 months of age. *Cognitive psychology*, *53*(4), 345–60. doi:10.1016/j.cogpsych.2006.05.003

Needham, A., Dueker, G., & Lockhead, G. (2005). Infants' formation and use of categories to segregate objects. *Cognition*, *94*(3), 215–40. doi:10.1016/j.cognition.2004.02.002

Nielsen, M., Simcock, G., & Jenkins, L. (2008). The effect of social engagement on 24-month-olds' imitation from live and televised models. *Developmental science*, *11*(5), 722–31. doi:10.1111/j.1467-7687.2008.00722.x

Pierroutsakos, S. L., & Troseth, G. L. (2003). Video Verité: Infants' manual investigation of objects on video. *Infant Behavior and Development*, *26*(2), 183–199. doi:10.1016/S0163-6383(03)00016-X

Pierroutsakos, S. L. (1999). *Understanding pictures as representations : 9-month-old infants' manual investigation of pictures as a function of referent characteristics.* (Unpublished doctoral dissertation). University of Illinois at Urbana-Champaign, Urbana, Illinois.

Quinn, P. C., & Schyns, P. G. (2003). What goes up may come down: perceptual process and knowledge access in the organization of complex visual patterns by young infants. *Cognitive Science*, *27*(6), 923–935. doi:10.1016/j.cogsci.2003.07.001

Rose, S. A. (1977). Infants' transfer of response between two-dimensional and three-dimensional stimuli. *Child Development, 48*, 1086–1091.

Roseberry, S., Hirsh-Pasek, K., Parish-Morris, J., & Golinkoff, R. M. (2009). Live action: can young children learn verbs from video? *Child development*, *80*(5), 1360–75. doi:10.1111/j.1467-8624.2009.01338.x

Salvucci, D. D., & Goldberg, J. H. (2000). Identifying fixations and saccades in eye-tracking protocols. *Proceedings of the symposium on Eye tracking research & applications - ETRA '00*, 71–78. doi:10.1145/355017.355028

Schmidt, M. E., Crawley-Davis, A. M., & Anderson, D. R. (2007). Two-Year-Olds' Object Retrieval Based on Television: Testing a Perceptual Account. *Media Psychology*, *9*(2), 389–409. doi:10.1080/15213260701291346

Schmitt, K. L., & Anderson, D. R. (2002). Television and Reality: Toddlers' Use of Visual Information from Video to Guide Behavior. *Media Psychology*, *4*(1), 51–76. doi:10.1207/S1532785XMEP0401_03

Scott, L. S., & Monesson, A. (2010). Experience-dependent neural specialization during infancy. *Neuropsychologia*, *48*(6), 1857–61. doi:10.1016/j.neuropsychologia.2010.02.008

Scott, L. S., Pascalis, O., & Nelson, C. a. (2007). A Domain-General Theory of the Development of Perceptual Discrimination. *Current directions in psychological science*, *16*(4), 197–201. doi:10.1111/j.1467-8721.2007.00503.x

Shields, P. J., & Rovee-Collier, C. (1992). Articles Long-Term Memory for Context-Specific Category Information at Six Months. *Child Development*, *63*(2), 245–259.

Slater, A., Johnson, S. P., Brown, E., & Badenoch, M. (1996). Newborn Infant ' s Perception of Partly Occluded Objects. *Infant behavior & development*, *19*(19), 145–148.

Slater, A., Morison, V., Somers, M., Mattock, A., Brown, E., & Taylor, D. (1990). Newborn and older infants' perception of partly occluded objects. *Infant Behavior and Development*, *13*(1), 33–49. doi:10.1016/0163-6383(90)90004-R

Slater, A., Rose, D., & Morison, V. (1984). New-born infants' perception of similarities and differences between two- and three-dimensional stimuli. *The British Journal of Developmental Psychology*, *2*, 287–294.

Strouse, G. a, & Troseth, G. L. (2008). "Don't try this at home": toddlers' imitation of new skills from people on video. *Journal of experimental child psychology*, *101*(4), 262–80. doi:10.1016/j.jecp.2008.05.010

Suddendorf, T., Simcock, G., & Nielsen, M. (2007). Visual self-recognition in mirrors and live videos: Evidence for a developmental asynchrony. *Cognitive Development*, *22*(2), 185–196. doi:10.1016/j.cogdev.2006.09.003

Troseth, G. L., & DeLoache, J. S. (1998). The Medium Can Obscure the Message : Young Children's Understanding of Video. *Child development*, *69*(4), 950–965.

Troseth, G. L. (2003). TV guide: Two-year-old children learn to use video as a source of information. *Developmental Psychology*, *39*(1), 140–150. doi:10.1037/0012-1649.39.1.140

Troseth, G. L.; Pierroutsakos, S. L.; DeLoache, J. S.. In *Advances in child development and behavior, Vol. 32*, by Troseth, G. L., Pierroutsakos, S. L., DeLoache, J. S., 1-35. San Diego, CA, US:Elsevier Academic Press, 2004.

Troseth, G. L., Saylor, M. M., & Archer, A. H. (2006). Young children's use of video as a source of socially relevant information. *Child development*, *77*(3), 786–99. doi:10.1111/j.1467-8624.2006.00903.x

Wartella, E., Richert, R. A., & Robb, M. B. (2010). Babies, television and videos: How did we get here? *Developmental Review*, *30*(2), 116–127. doi:10.1016/j.dr.2010.03.008

Zimmerman, F. J., Christakis, D. a, & Meltzoff, A. N. (2007). Television and DVD/video viewing in children younger than 2 years. *Archives of pediatrics & adolescent medicine*, *161*(5), 473–9. doi:10.1001/archpedi.161.5.473