EFFECTS OF CATEGORIZATION ON OBJECT INDIVIDUATION IN INFANTS: AN EYE-TRACKING STUDY

An Undergraduate Research Scholars Thesis

by

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ABSTRACT

Effects of Categorization on Object Individuation in Infants: An Eye-tracking Study

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Infants' representation of objects is critical in learning about their environment and the way objects within the environment interact with each other. Two aspects of object processing that contribute to this understanding are interpretation of occlusion events and identifying event categories of three-dimensional objects. The use of eye-tracking technology allows us to analyze in detail the looking patterns of infants during these events and uncover more about the nature of infant representations of their physical environment. The current study examines the effect of forming categories – and assigning objects to a category – on object tracking. Using an eye-tracker, infants aged eleven to nineteen months were given experience observing the functions of rollers and cutters before examining an occlusion event in which one of the objects moved along a linear path, disappeared behind a screen, and emerged on the other side: either as the same object or a different object. We found two main effects: First, infants were more able to accurately track an occluded object after they experienced training trials. Second, infants also more accurately tracked the occluded object during the one-object event than the two-object event.

DEDICATION

We dedicate this research to Marisa Biondi and Dr. Teresa Wilcox. Thank you for going above and beyond as mentors.

NOMENCLATURE

AOI	Area of Interest

CHAPTER I

INTRODUCTION

The ability to distinguish between objects is paramount in learning about our physical environment, both in the relationship between objects and mapping objects in space and time. Not only can infants represent the existence and physical properties of objects (Woods, Wilcox, Armstrong, & Alexander, 2010), but also from as early as two months of age infants are able to detect visual discrepancies in scenes (Bronson, 1982). Studies on this topic have examined either infant visual scanning patterns in response to occlusion events, or the effect that event category training – training on the specific roles of objects – has on object individuation (Wilcox, 1999). This study will examine the interaction between these two concepts in order to gain a more holistic understanding of how infants use objects to learn about their environment.

Despite Piaget's early theories, from a very young age, infants understand that objects continue to exist even when the object is hidden. However, infants do not always represent detailed information about those hidden objects. That is, even though infants know that the object still exists, they may not understand where or how the object is moving. Even though objects are moving in and out of view regularly in the environment, infants have difficulty keeping track of these objects when they cannot see them. This may be because infants must establish whether the object they saw before it was hidden is the same object they saw re-appear in order to correctly individuate objects. It may also be because, unlike adults, infants have trouble integrating featural information (physical features of an object), physical information (how objects move and interact), and experiental knowledge (what objects and categories exist in the world) with which to tell one object from another (Wilcox & Baillargeon, 1998). However, some research has shown that increased exposure to complex occlusion events allows infants to form a physical representation, which increases accuracy in tracking objects during these events (Baillargeon, et al., 2012).

Research has also found that infants find it easier for infants to track one object than two objects, even when the trajectory of the objects is the same. Woods and colleagues (2010) presented infants with an occlusion event that involved a ball starting on the left side of the screen that then disappeared behind an occluding screen. Another object then reappeared from behind the occluding screen that either matched the first object (ball) or was different from the first object (box). The researchers found that during the ball-ball event, infants were better able to predict the path of the object even when the object was behind the screen. From this information, the researchers deduced that infants in the ball-box event found it more difficult to represent the occlusion sequence. Using this information, we hypothesized that infants in the two-object condition in our experiment would yield the same results as the infants in the box-ball condition – that is, presenting infants with an occlusion event with one object event would lead them to better predict the trajectory of the object, as opposed to an occlusion event with two distinct objects.

One thing we are interested in exploring for the present study is what makes it *easier* for infants to represent objects through an occlusion sequence. Previous research has found that infants are more susceptible to learning from functional events in which an object is assigned a specific function or task. An experiment done by Wilcox & Chapa (2004), researchers found that infant learning is guided by function-based events. This means that infants learn the functional relationship between different parts of an object and use inferences they make about a function of an object to form categories, and then extend those inferences to similar objects. In this study, researchers presented babies with different pairs of cups. One cup from each pair was red, and the other was green. The red cups were always used to scoop sand, and the green cups were always used to pound a wooden peg. Infants were then shown occlusion events in which a red ball disappeared behind a screen, and a green ball re-appeared. The result was that after seeing examples of the function of the red and green cups, infants were surprised when the red ball "changed" to green. This surprised reaction leads us to believe that the infants were engaging in individuation. This suggests that by linking a function to these colored objects, researchers were able to prime the infants to use color as an identifying feature in order to individuate the objects. In the present research, we take this same idea and apply it to more complex objects.

Taking findings from these two experiments, the purpose of our experiment was to determine whether increased experience learning the function of objects that most infants were likely unfamiliar with (in this case, rollers and pizza cutters) would help infants accurately infer where the object was even if they could not see it. We hypothesized that demonstrating the function of these objects would lead infants to attend to the correct side of the occlusion screen that contained the hidden object. Since we are working with a pre-verbal age group, the use of eye-tracking technology allows us to examine how infants scan a visual scene. Through this examination of gaze behavior, we are able to generalize how infants acquired knowledge about these events. Eye-tracking employs high temporal and spatial resolution, resulting in rich data sets and increased accuracy in measurement, as compared to general looking time often used in infant studies. We can examine the exact saccade, or eye movement between fixation points, in specified areas of interest in a relatively short time period.

CHAPTER II

METHODS

Participants

Nineteen healthy infants, age 11 to 18 months (*M* = 474.61 days , *SD* = 65.60 days, F=12) participated in this study. Infants were excluded if they were fussy (n = 4) or had low attention (n = 5). Low attention was defined as contributing looking-time data for fewer than two pre-training trials and fewer than two post- training trials. Each infant saw the same trial order. All infants for this study were recruited from commercially produced lists and emails sent out to Texas A&M University faculty and staff. The experimental protocol was approved by the Institutional Review Board. Informed consent was given to parents before testing, and parents were debriefed after the study. Parents were given either $5 or a lab T-shirt in exchange for participation.

Setup

The events were filmed in a puppet-stage apparatus and later presented on an eye-tracking screen. The illuminated puppet-stage apparatus contained a white poster board as a base, with a patterned backdrop. During the occlusion events, a blue 10-inch X 12-inch occlusion screen was situated in the middle of the backdrop, halfway between the backdrop and the front of the apparatus. This screen was used to occlude objects presented to the infants in the pre- and post-training events. The setup for the training trials included the same backdrop and base as the test trials, but also contained a clear rotary board with a piece of blue Play-Doh on the right side of the apparatus. The objects used in the pre- and post-training included a pair of pizza cutters and dough rollers; one pair used for the two-object events and a single roller used for the one-object events. The training trials included three pizza cutters and three rollers, with the sequence shown alternating between roller and cutter. Each pizza cutter was always presented with the same roller, with numbers written on the bottom so that the experimenter could differentiate the pairs.

Infants sat in their parent's lab approximately 60cm from the Tobii T60XL eye-tracker's display screen. Parents were asked to wear blacked-out glasses in order to ensure that the eye-tracker picked up only the infant's gaze. Before the experiment video was presented, the experimenter obtained a calibration that included five points. A minimum of three of the five points per eye was required to continue testing. A camera was placed above the eye-tracker in order to monitor the infant during the study.

Experiment

Pre- and post-training

Infants were presented with nine pre-training and post-training trials. The trials alternated between one-object (e.g., where the object on the left and right of the screen did not change) and two-object (e.g., where the object on the left and right of the occlusion screen changed). A total of nine trials were presented, with five of them one-object events and four of them two-object events.

For all trials, the experimenter manipulating the objects wore a long black glove. Each of the pre- and post-test trials lasted ten seconds. The experimenter followed a precise, timed script. A metronome was turned on at the speed of 60 beats per minute, and the board in front of the experimenter was marked to indicate where the experimenter's hand should be placed at each second. The time course proceeded as follows: the roller would move from the left side of the screen, towards the occluder for the first two seconds, then disappear behind the occluder. Then, either the roller or cutter would appear to the left side of the screen for two seconds. The final object would maintain its position on the right side of the screen while the blue occluder screen rotated forward to reveal a blank stage behind it. Since infants only had to follow the trajectory of one object, we expected the infants to correctly track the object in this event more than in the two-object event.

The two-object events required two experimenters to manipulate the two different objects to give the illusion that the same hand was holding both different objects. The time distribution remained the same, however now each time an object disappeared behind the occluder, the other object would re-appear on the other side. This gave the illusion of the roller “changing identity” into the cutter. As with the one-object trials, the final scene was the blue occluder screen rotating down to reveal a blank stage behind it. We predicted that infants would be surprised by the objects changing identity, and therefore would not be as successful at correctly tracking the objects as in the one-object event.

Training trials

Infants were presented with six, ten-second-long training trials during which the experimenter alternated between three rollers and three pizza cutters. To get the infant’s attention, the experimenter would wave before the beginning of every trial. The experimenter then demonstrated the function of these objects by either flattening a log of Play-Doh with the rollers or cutting it with the pizza cutters. In order to ensure that timing was uniform across trials, a metronome was set to 60 beats per minute. The time distribution for the events were as follows: for the roller, the experimenter would wave her hand for two seconds, pick up the roller, and place on play-doh for two seconds, roll forward for two seconds, roll backward for two seconds, and then roll forward for two seconds. The timing was the same for the cutting trials, except instead of rolling the dough, the cutter would cut through the Play-Doh forward for two seconds, roll backward for two seconds, and cut forward again for two seconds.

Data extraction and analyses

All looking time data was extracted from the Tobii Studio program (Version 3.2.1). For our analyses we calculated mean looking time for four AOIs per trajectory (for the first segment when the object was moving left to right, and the next segment when the object was moving right to left). The first AOI was the left side of the screen where the object initially started, the next was the left side of the occluding screen, then the right side of the occluding screen, and finally the right side of the screen where the object re-appeared (Figure 2).

Using these looking times, we then calculated "percent correct" collapsed across all participants, which acted as our dependent variable. This was the percentage of time that infants were looking to the side of the occluding screen behind which the object was hidden at that point in time (e.g. if the object was behind of the left side of the occluder, the infant would have to be looking on the left side of the occluder for the looking time to count as "correct"). Here, we were assuming that if infants were correctly tracking the object, then they would be more likely to attend to the side of the occluder where the object actually was. To do this, we first divided the total time infants were looking at the occluding screen only by the total time the infants looked at the entire display for all pre-training and post-training trials. By separating the left and right side of the occluding screen, we were able to calculate how long infants looked to the left of the occluding screen when the object was actually on the left and vice-versa when the object was moving from left to right and from right to left. Using this percent correct variable allowed us to determine whether or not the infant was correctly predicting, or anticipating, where the object was even when the object was hidden.

CHAPTER III

RESULTS

Phase

To test whether or not providing infants with experience learning the function of these objects helped them to track the objects through occlusion, we ran a repeated measure ANOVA with phase (pre-, post-training) as a within-subjects factor. This revealed a main effect of phase ($F(1,18) = 8.21$, $p = .005$) indicating that the infants attended to the correct side of the screen for a greater percentage of time after training than before training, whether or not they saw the one- or two-object event (Figure 3). Prior to the training trials, infants affixed to the correct side of the screen 16.8% of the time. After the training trials, infants affixed to the correct side of the screen 26.8% of the time.

Event

To test whether or not infants were in fact individuating the objects (determining how many objects were involved), we also ran a repeated measure ANOVA with event (one- or two-object) as another within-subjects factor. This resulted in a main effect of event ($F(1,18) = 10.04$, $p = .01$) showing that infants in the one-object condition attended to the correct side of the screen a greater percentage of time than infants in the two-object condition even when they had gained experience with the function of the object (Figure 4). When infants were shown the same object, they affixed to the correct side of the screen 24.3% of the time. When infants were shown two different objects, they affixed to the correct side of the screen 19.2% of the time.

CHAPTER IV

DISCUSSION

Our experiment resulted in two significant outcomes. First, infants were more successful at determining the correct location of an occluded object after the training trials in which the function of the object was demonstrated. These results were significant in both the one-object and two-object condition. This supports our prediction that helping infants categorize objects allows them to more accurately track objects through occlusion. This also supports previous research suggesting that demonstrating the function of an object helps infants to engage in object individuation (Wilcox & Chapa, 2004).

Second, as seen in previous experiments (Woods et al., 2010), infants were more successful at tracking the occluded object during one-object events than during two-object events. This is likely due to the fact that infants were having to track changes in direction of both objects. Wilcox and Baillargeon's (1998) research on infants' use of featural information to individuate objects during occlusion events found that an important distinction to make when interpreting these data is that between event mapping, in which infants see two distinct events and must deduce whether or not the events are consistent, and event monitoring, in which infants see only one event and judge whether the separate parts of the event are consistent. These findings are consistent with our results, which showed that infants were better able to correctly infer the position of the occluded object when only one object was moving back and forth behind the occluding screen.

In the real world, objects are constantly moving in and out of view. In order to navigate our environment, we must learn early on how to track objects through space and time to correctly infer the object's location. Much of the previous research has focused mainly on how infants use featural information, such color, shape, and size to categorize objects. In this study, we investigated how learning functional information about more complex objects helps infants correctly track the object through occlusion.

This research provides some intriguing findings as to how infants develop and use categories of representation that are based on information they learn about how the object works. Future studies should be done in which infants are shown events that do not lead to the development of event categories. This will help us to determine to what extent category formation and understanding the function of an object helps infants map events, versus other factors such as simply learning the object's trajectory through repeated trials.

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APPENDIX A

Figure 1. Examples of stimuli in training trials (L: Cutter, R: Roller); each infant saw 3 cutter and 3 roller events on alternating trials.

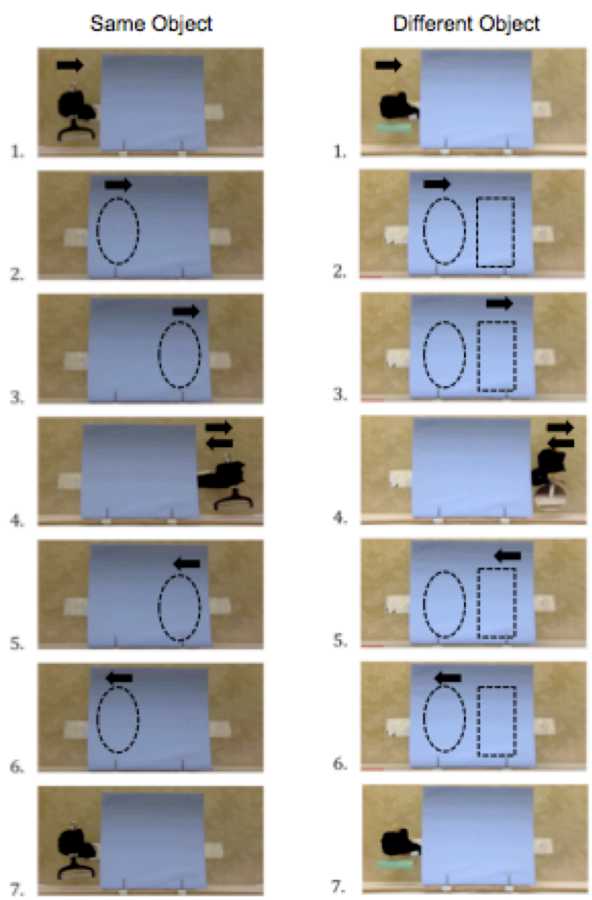

Figure 2: Diagram depicting the trajectory of same and different object events with AOIs used to calculate percent correct. The dotted oval indicates the location of the roller during occlusion, while the dotted rectangle indicates the location of the cutter.

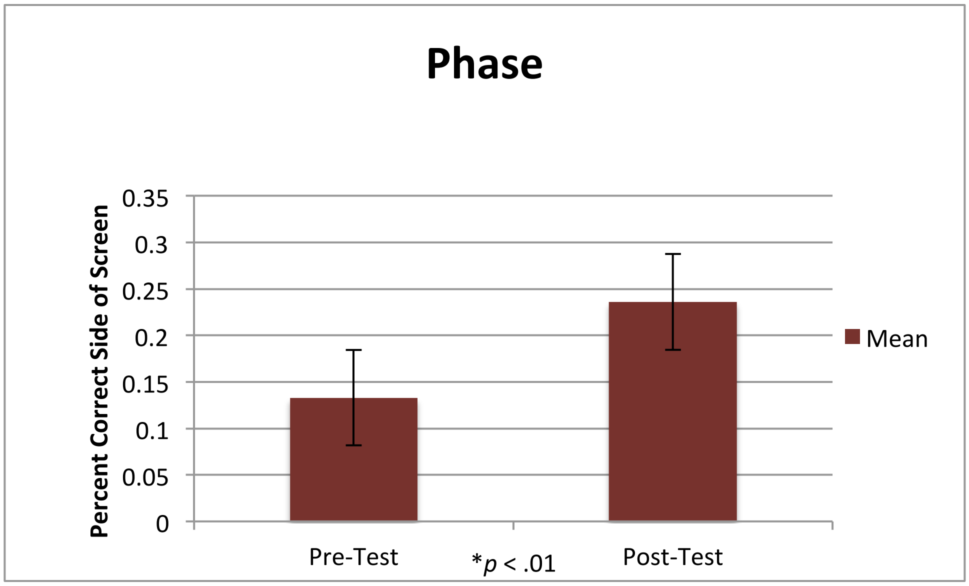

Figure 3: Graph showing main effect for phase; infants were more likely to look longer to the correct side of the screen after training than before training, regardless of whether the event was one-or two-object.

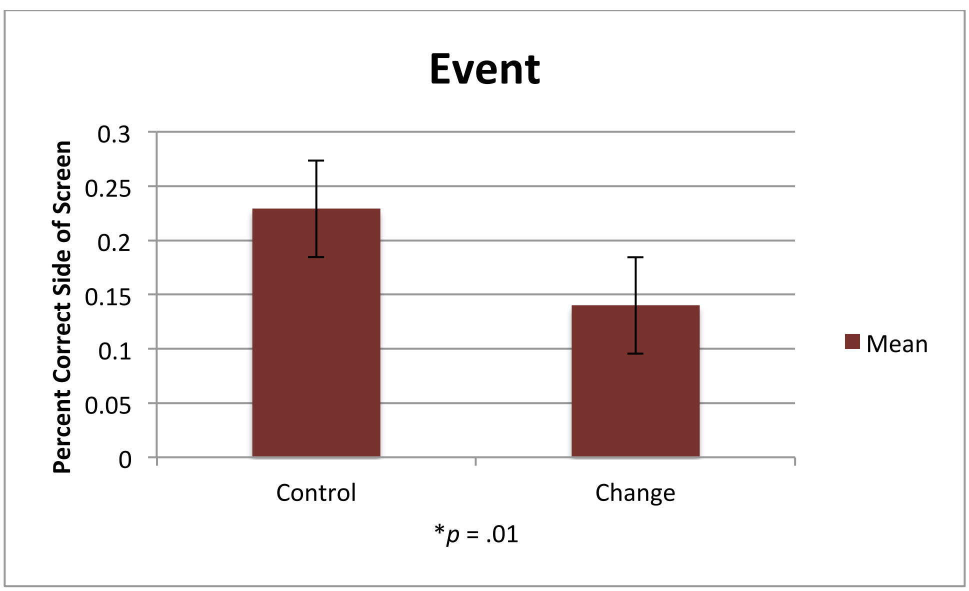

Figure 4: Graph depicting the main effect for event; infants were more likely to look to the correct side of the screen during the control (one-object) event than during the change (two-object) event before and after training.