OBJECT INDIVIDUATION USING FUNCTION IN INFANCY: AN EYE-TRACKING STUDY

A Thesis

by

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ABSTRACT

The age at which infants are able to individuate between objects on the basis of the functional category to which it belongs has yet to be determined. Object individuation depends on a variety of object characteristics such as function, color, shape, or name, as well as infant characteristics such as age. Recently, research has emphasized the importance of individuation using functional information in infancy. In this study, looking time performance for infants aged 3- to 8 months and 12- to 18-months was evaluated using eye-tracking technology to assess infants' abilities to individuate objects based on functional categories. Infants were either given the opportunity to create a functional category (i.e., roller and cutter) by viewing functional examples in the Experimental Condition, or they were not given this opportunity in the Control Condition.

Across both conditions no significant differences were found among looking time during the final phase of the test trials for infants aged 3- to 8- months, but there was a significant difference between the scores for the Experimental Condition (M = 0.4303; SD = .244) and the Control Condition (M = 0.2965; SD = .230) during the second test trial; t(87) = 2.596, p = 0.011, *d* = 0.278. In addition, there was a significant difference in the scores for Experimental (M=0.4827, SD = 0.268) and Control (M = 0.326, SD = 0.171) Conditions during the third test trial; t(87) = 3.099, p =0.002, *d* = 0.332. Additionally, there was a significant difference between the percent-to-center looking times for Trial 1 (M= 0.302, SD = 0.196) and Trial 2 (M = 0.430, SD = 0.244);

$t(52) = -3.896$, $p < .01$, $d = -0.540$; and Trial 1 and Trial 3 ($M = 0.483$, $SD = 0.268$); $t(52) = -4.099$, $p < .01$, $d = -0.568$ for infants aged 12- to 18- months. This suggests that infants aged 12- to 18- months, but not 3- to 8- months, are able to use functional information to establish categories and use this functional category information to later individuate objects based on function.

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Data collection was provided by undergraduate research assistants, in collaboration with the student. All other work conducted for the thesis was completed by the student independently.

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1.0 INTRODUCTION

Categorization of the world around us is a foundational cognitive effort of all humans. It is therefore a key developmental milestone that infants learn to assess their environment via a variety of characteristics to better categorize objects (Booth, 2006; Booth & Waxman, 2002; Hernik & Csibra, 2009; Hernik & Csibra, 2015; Hernik & Southgate, 2012; Kingo & Krøjgaard, 2011, 2012; Wilcox & Biondi, 2015). Object individuation, or the ability to recognize whether two objects are the same or different based on pre-existing knowledge, is also one of the most basic cognitive processes in which humans engage (Wilcox, 2003). Early in development, during infancy, humans have been shown to use categorical information to identify and group objects within their environment (Stavans & Baillargeon, 2016; Tremoulet, Leslie, & Hall, 2000; Wilcox, Smith, & Woods, 2011). In addition, an infant's ability to individuate objects has been shown to depend on the developmental age of the child; as well as developmental milestones, such as language acquisition and fine motor development (Balaban & Waxman, 1997). Infants' abilities to understand object differences and provide labels for such differences is facilitated by their language and motor developmental levels which are acquired throughout the first two years of life (Balaban & Waxman, 1997; Krøjgaard, 2000, 2004; Zosh & Feigenson, 2012). Currently there is an abundance of research on infants use of featural information to categorize objects, first with color, shape, and form; but not much data is focused on the use of functional information (Hernik & Southgate, 2012; Krøjgaard, 2000, 2004; Oakes & Madole, 2010;

Wilcox & Chapa, 2004; Wu et al., 2011). The present study provided and assessed exemplars of functional objects to facilitate the development of categories, which is believed to assist in subsequent individuation of objects in infants greater than, but not younger than, 12-months-old.

Research has demonstrated individuation-by-function as early as age four months when two different function categories were demonstrated for the infants (Stavans & Baillargeon, 2016). Furthermore, Träuble & Pauen (2007) found that infants aged 11-12 months were only able to differentiate functional objects once the object function was demonstrated, suggesting that infants aged one-year use functional information to cue object individuation. Previous experimental tasks and research designs have included objects that have different forms, shapes, colors, and/or functions, which has shown early individuation in infants (Sloutsky, 2003; Stavans & Baillargeon, 2016; Tremoulet, Leslie, & Hall, 2000; Wilcox & Chapa, 2004; Xu, Carey, & Quint, 2004). Researchers have studied the development of individuation based on color, shape, and features developed earlier in infancy in abundance, but less research has focused on the development of individuation on the basis of category or kind information (Balaban & Waxman, 1997; Bornstein & Mash, 2011; Kemler Nelson, Frankenfield, Morris, & Blair, 2000; Rakison & Butterworth, 1998). The individuation of objects is additionally facilitated by the infants' ability to categorize objects based on kind information.

Categorization literature suggests that infants categorize novel, complex objects based on function around age 12 months (Booth, 2006; Booth & Waxman, 2002; Hernik & Csibra, 2009; Hernik & Csibra, 2015; Träuble & Pauen, 2007). Previous research illuminates specific time periods of development, such as ages 9 months, 12 months, and 18 months which are of specific interest in object recognition and individuation (Hernik & Southgate, 2012; Tremoulet et al., 2000; Wu, Gopnik, Richardson, & Kirkham, 2011; Xu et al., 2004; Zosh & Feigenson, 2012). Around 9 months old, infants begin to understand goal-directed behavior, such as using objects to perform a function (Hernik & Southgate, 2012). Infants of this age have also been shown to be sensitive to patterns and visual stimuli when presented with object categories, but when task difficulty increases infants aged 9 months were unable to complete the categorization task without the assistance of social cues (Wu et al., 2011). As such, infants aged 9 months old demonstrate the initial attributes necessary for categorization based on function with compensatory social cues. At 12 months, the influence of both size and shape on individuation is tremendous which can influence infants' abilities to categorize and later individuate based on functional information which uses size and shape to identify the function (Tremoulet et al., 2000; Xu et al., 2004). Lastly, object individuation among infants aged 18 months have been shown to be affected by memory load, such that increasing memory demands hinders infants' abilities to individuate objects later on (Zosh & Feigenson, 2012). In essence, these studies demonstrate the development of necessary abilities infants may need to individuate based on functional information, and little is known about the conditions under which infants can build functional categories and then later individuate on the basis of those categories.

One way to facilitate the creation of a category based on kind information is to provide information about the functional use of objects. This has been done by showing infants multiple exemplars demonstrating the function of specific objects. The present study used objects with similar forms, including a handle and spinning apparatus that performs the function (Figure 1). This provided infants with an opportunity to build a functional category so that we could test their capacity to individuate objects in the following test trials on the basis of the category in which the objects belong. Infants individuate objects on the basis of the category to which the object belongs, rather than the individual features like shape, size, or color (Wilcox et al., 2011). These characteristics are demonstrated in a variety of priming tasks in the current literature which support the categorization of objects based on kind (Brower & Wilcox, 2013; Wilcox & Chapa, 2004; Wilcox et al., 2011). Presenting categorical exemplars to facilitate categorization of objects based on a specific kind (i.e., function) prior to a violation-of-assumption task is believed to facilitate the individuation of objects during such tasks (Baillargeon et al., 2012; Mikołaj Hernik & Csibra, 2015).

EXPERIMENTAL CONDITION
Familiarization Trial 1:

Familiarization Trial 2:

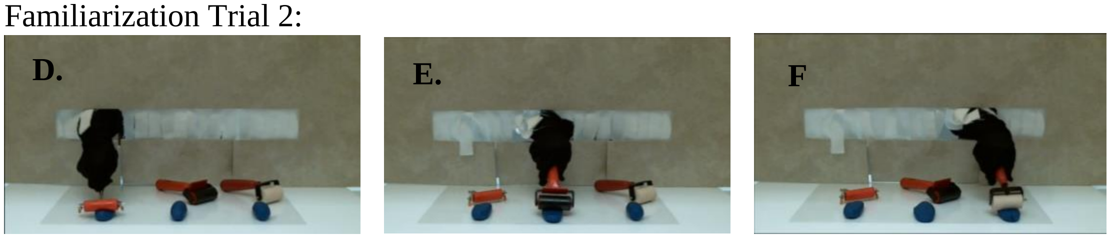


Figure 1. Exemplars of Function for each Category in Experimental Condition. Familiarization Trial 1: Three different "cutters," objects A, B, and C, were presented for 12 seconds each, totaling a 36 second trial. Familiarization Trial 2: Three different "rollers," objects D, E, and F, were presented for 12 seconds each, totaling a 36 second trial.

To control for the possibility that watching objects engage in functions, in and of itself, and not the building of object categories, leads to individuation-by-function; another group of infants were tested in a control condition. In the control condition, familiarization trials composed of mixed exemplars were presented to the infants, thus being exposed to objects engaging in their specific functions but hindering the infants' ability to construct a category based on function (Figure 2). Research has demonstrated that when exemplars are mixed, infants typically do not build categories (Balaban & Waxman, 1997; Booth, 2006). A focus of the present study was to investigate the extent to which infants' ability to build functionally relevant object categories influenced their ability to individuate objects based on the categories formed during a demonstration of functional exemplars.

CONTROL CONDITION

Familiarization Trial 1:

Familiarization Trial 2:

Figure 2. Exemplars of Function for each Non-Category in the Control Condition. Each trial lasted a total of 12 seconds and the timing is identical to that of Experimental Condition shown in Figure 1. Familiarization Trial 1: Three different objects were presented for 12 seconds each in the pattern of cutter (A)– roller (B) – cutter (C), totaling a 36 second trial. Familiarization Trial 2: Three different objects were presented for 12 seconds each in the pattern of roller (D) – cutter (E) – roller (F), totaling a 36 second trial.

Previous research, in addition to the present study, assessed infant individuation via violation-of-assumption paradigms (Figure 3). In these tasks, infants demonstrate the ability, or lack of ability, to distinguish objects while one object moves behind a screen and another, different object emerges.

Figure 3a: Pre-Occlusion (4s)

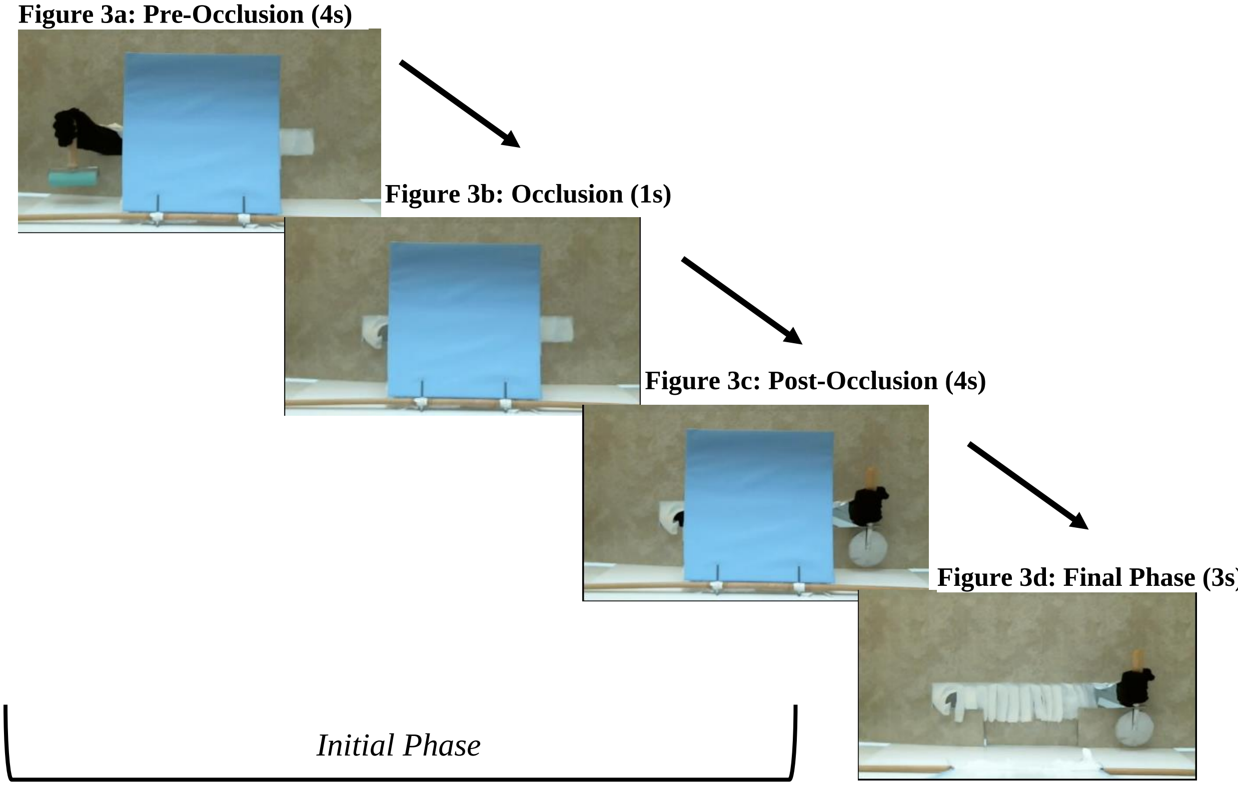


Figure 3. Violation-of-Assumption Paradigm. Figure 3a – 3c depict the events of the Initial Phase, figure 3d depicts the image of the Final Phase. The entirety of the test trial is 12 seconds, moving at a rate of 6 cm/s during the initial phase. (3a) Pre-occlusion: A roller is presented to the left of the screen for 3 seconds before moving to the Occlusion phase. (3b) Occlusion: The roller and cutter are hidden behind the screen for 2 seconds before the cutter moves out to Post-Occlusion. (3c) Post-Occlusion: The cutter is exposed on the right of the screen and holds for 4 seconds before the screen rotates down for the Final Phase. (3d) Final Phase: The screen is rotated down and the cutter is exposed for 3 seconds.

It is believed that infants will look longer at novel objects after an occlusion event, suggesting they are assessing whether the object is the same, or different, than the previously shown object (Stavans & Baillargeon, 2016). If infants infer there are two different objects, they will expect to see a second object behind the screen after it is lowered. Therefore, when infants are able to individuate objects they will show longer looking times to the center of the platform where they would expect to see the second object, this inference is demonstrated by increased looking time to the center of the platform. If infants have not individuated, they will not find the presence of only one object on the platform unexpected.

We aimed to assess the developmental progression of the use of functional information to individuate objects using eye-tracking software to determine the approximate age group at which infants are, on average, able to build object categories and then individuate novel objects on the basis of the category to which they belong within the first 18 months of development. This will be demonstrated by using group comparisons of 3- to 8-month-old infants and 12- to 18-month- old infants. On the basis of research on infants' ability to build functional categories (Träuble & Pauen, 2007) it is expected that the older, but not the younger, infants will be successful on this task. In addition, eye-tracking software provides more data to assess whether infants' gaze followed an object through occlusion, and whether they were able to individuate based on function by calculating looking time to the center of the screen (Figure 3) (Wilcox & Chapa, 2004).

1.1 HYPOTHESIS

The experimental design in this study is novel such that functional exemplars were presented during the familiarization trials to facilitate the categorization of a group based on function (Figure 1). Infants pseudo-randomly assigned to Control Condition were presented with non-category familiarization tasks prior to the test trials (Figure 2). Following the familiarization trials in both conditions, infants observed the test trials, which demonstrated the event-mapping task (Figure 3).

If infants were capable of building functional categories in the familiarization trials of Experimental Condition, and then individuate objects in the test trials based on the category to which the objects belong, they should show prolonged looking time to the center of the platform. Looking to the center of the platform indicates the infant was aware of the presence of two distinct objects and expected to see another object behind the screen when it was lowered for the Final Phase of the test trials (Figure 3d). It was expected that older infants would demonstrate the ability to individuate the objects in the test trials using the categories created in the familiarization trials of Experimental Condition. In addition, older infants, aged 12- to 18- months, were predicted to show prolonged looking time compared to younger infants, aged 3- to 8- months. Older infants in the experimental condition, Experimental Condition, were hypothesized to show longer looking times, or increased percent-to-center looking times, than infants in the control condition, Control Condition.

2.0 METHODS

*2.1 P*ARTICIPANTS

Infant ages 3- to 8- months (*n* = 83) and 12- to 18- months (*n* = 89) were recruited through the Aggie Network, social media, and local businesses. These two age groups were selected due to previous literature highlighting differences in individuation between these age groups. Participants were 172 infants age 3 -months, 1- day to 18- months, 27- days (mean age = 320 days, range = 91 to 567 days). An additional 60 infants were tested but eliminated from the final sample because of infant activity (*n* = 14), failure to complete three pairs of test trials (*n* = 10), inability of the eye tracker to capture the infant's eyes (*n* = 16), parent interference (*n*= 4), premature (<35 weeks) birth (*n*= 7), or researcher error (*n*= 9). There were more male infants (95 participants; 55%) than female infants (77 participants; 44%). A similar number of infants were assigned to the Experimental Condition (39 infants aged 3- to 8- months; 53 infants aged 12- to 18- months; N = 92) and the Control Condition (44 infants aged 3- to 8- months; 36 infants aged 12- to 18- months; N = 80) conditions. Infant participants were pseudo-randomly assigned to either Experimental Condition or Control Condition.

Parents and their infants attended a 15- to 20-minute appointment for which they were reimbursed for time and effort with either $5.00 or an infant tee shirt. Parents reported their infant's ethnicity as Hispanic (*n*= 31), Non-Hispanic (*n*= 136), and Unknown (*n*= 5). Parents reported their infant's race as Caucasian (*n* = 127), African American (*n* = 8), Asian (*n* = 15), mixed race (*n* = 12), or other (*n* = 10). The procedure was explained to the parents and informed consent was obtained prior to testing.

2.2 MATERIALS AND PROCEDURES

Infants sat in a parent's lap approximately 60-80 cm from a 24- inch monitor used to present the stimuli. Stimuli was prepared using Tobii Pro Studio – version 3.4.8. Each stimulus event included a video recording of two familiarization trials, followed by four test trials. A remote eye tracker (Tobii T60 XL) was used to measure eye movements during stimulus presentation. The infrared corneal reflection eye tracker was embedded in the lower portion of a 24-inch flat screen monitor (17.7W TFT l flat screen monitor) (resolution: 1024 × 768 pixels) and detected the position of the pupil and the corneal reflection of the infrared light from both eyes. The Tobii T60 XL records data at 60 Hz with an average accuracy of 0.5° visual angle and a head movement compensation drift of G0.1. Fixation data were defined using the Tobii fixation filter (version 2.2.8) with a velocity threshold of 35 pixels and a distance threshold of 35 pixels. Total duration of looking during each test trial and for each AOI was calculated by the sum of fixation data for that trial and AOI. The monitor was mounted on an adjustable arm so that it could be positioned optimally for each infant. A Logitech Webcam Pro 9000 was placed directly below the monitor to record a full-face view of the infant during stimuli presentation. The stimuli were presented using professional visualization software (Tobii Studio) on a desktop computer.

During the experiment, parents wore darkened sunglasses to prevent the eye-tracker from reading the parent's eyes. Prior to the experiment, the system was calibrated to the infant by presenting a duck accompanied with a bell sound. The duck was presented at five different points including the four corners and the center of the screen.

During both the familiarization and test trials, an experimenter and observer recorded written notes on successful eye-tracking, the presence of the infant on the video recorder, and behavioral observations of the infant and parent.

2.3 EXPERIMENTAL CONDITION EVENTS

The Experimental Condition presented category familiarization trials to facilitate building roller and cutter categories. The two familiarization trials were presented first, followed by four test trials. The 12- to 18-month-old, but not 3- to 8-month-old, infants were expected to use this information to create categories based on the functional information they receive during the first two familiarization trials.

Experimenters wearing black gloves produced all of the trial events following a precise script. The time taken to produce the actions described in all trials, familiarization and test, are included in the descriptions below. All objects used included a variety of colors and sizes of tools to isolate the function of each object and avoid other priming effects.

2.3.1 Experimental Condition Familiarization Trials

Each infant was first presented with two same-category familiarization trials. The first trial depicted a set of three individual cutting tools, henceforth referred to as “cutters,” demonstrating the category function by cutting modeling clay (Figure 1) totaling 36 seconds. The first demonstration lasts 0-12 seconds; during the demonstration, the hand waves (3s), picks up the first cutter (3s), places it in the center of a pre-cut, blue modeling clay log (1s), and cuts back-and-forth three times dividing the modeling clay into two equal halves (5s). The cutter returns to the floor of the platform. The hand will then raise, move the fingers in a forward waving motion, one finger at a time (3s). The same steps are repeated using the second cutter and lasts 13-24 seconds. The hand then proceeds to the third cutter, repeating the same procedure as the first two cutters for 25-36 seconds. Between the first familiarization trial (i.e., cutters) and the second familiarization trial (i.e., rollers), the infant is shown a brief display with a star (1s), presented at the center of the screen, and bell noise to maintain the infant's attention and orientation to the screen.

The second familiarization trial was identical to the first familiarization trial except it includes three individual rolling tools, henceforth referred to as "rollers," which demonstrates their function by flattening modeling clay (Figure 1) for a total of 36 seconds. A brief five- star display (3s) and bell noise are presented in the four corners and the center of the screen at the conclusion of the familiarization trials and indicate the transition to the test trials. This display maintains the infant's attention to the screen and orients them to the center of the image before the test trials began.

2.3.2 Experimental Conditions Test Trials

Following the two familiarization trials, the infant was presented with the four test trials. Each test trial consisted of an initial phase during which a roller is presented to the left of an occlusion screen, termed pre-occlusion (Figure 3a). After three seconds the roller moves behind the screen, the occlusion event (Figure 3b), and a cutter appears to the right of the screen. The cutter is presented for an additional two seconds, termed post-occlusion (Figure 3c), prior to the screen lowering. The screen then lowers after eight total seconds from the onset of the trial to begin the final phase (Figure 3d). Upon conclusion of the final phase, the star screen appears to maintain the infant's attention and maintain orientation to the center of the screen. This process is repeated for four total test trials. Upon concluding the fourth and final test trial, the research assistant reviewed the video with the parent who then remove the darkened glasses and had the opportunity to ask questions.

2.4 CONTROL CONDITION EVENTS

Control Condition presented the non-category familiarization trials and acts as the control condition for this study. The goal of including a control condition was to evaluate the influence of seeing objects on infant attention when no categories are built, when compared to the experimental condition, during which categories are built. The procedures are identical to Experimental Condition except for the arrangement of the rollers and cutters in each familiarization trial.

2.4.1 Control Condition Familiarization Trials

Each infant was first presented with two non-category familiarization trials. The first trial depicted a set of three individual tools in the sequence of cutter – roller – cutter for a total of 36 seconds (Figure 2). The procedure is identical to that of Experimental Condition familiarization trial 1 except for the orientation of tools, now oriented as cutter – roller – cutter. Infants should not be able to build a category in this condition because they will not see three consistent exemplar demonstrations (i.e., the exemplars are mixed).

The second familiarization trial includes the inverse of the first familiarization trial in Control Condition with three objects in the order of roller – cutter – roller a total of 36 seconds (Figure 2). This is identical to the previously described familiarization trials in time and stimulus. A brief five- star display (3s) and bell noise was presented in the center of the screen at the conclusion of the familiarization trials and indicated the transition to the test trials.

2.4.2 Control Condition Test Trials

Following the two familiarization trials, the infant was presented with the four test trials. The test trials in Control Condition are identical to those presented in Experimental Condition.

2.5 DATA CODING

Within Tobii Studio, the variable "Total Fixation Duration" was extracted and used to calculate looking time. Total fixation duration is defined as the amount of time a participant focuses on an area of interest (AOI) established by the researcher, based on stimulus presentation. Areas of interest (AOI) will be discussed in the next section. The total fixation duration variable in Tobii studio best reflects looking time. Previous literature has not utilized eye-tracking software, but routinely evaluates looking time as an assessment of infant attention (Wilcox, Hirshkowitz, Hawkins, & Boas, 2014; Xu et al., 2004). Therefore, total fixation duration was selected as the variable to extract and analyze as it is consistent with previous literature. The mean total fixation duration was extracted and imported to the Statistical Package for Social Sciences (SPSS) for further analysis.

In the test trials, if infants individuate they will expect a second object behind the center screen when the final phase commences. Therefore percent-to-center times were calculated using AOI information. Specifically, the looking time to the center AOI for each trial is divided by the total looking time across all three AOIs (Formula 1). This approach, commonly used in infant research, standardizes looking to the center platform on the basis of infants' overall attention to the trial.

Formula 1:

$$\frac{\text{Looking time (Center)}}{\text{Looking time (Left + Center + Right)}}$$

2.5.1 Familiarization Trials

Each familiarization trial included three areas of interest (AOIs), one for each object presented on the screen (Figure 4). For Experimental Condition, the AOIs were labeled as Cutter One, Cutter Two, and Cutter Three in the first familiarization trial (Figure 4a); and Roller One, Roller Two, and Roller Three in the second familiarization trial. Control Condition included AOI labels, Mixed 1, Mixed 2, and Mixed 3 for both trials. Figure 4b presents the AOIs for the first familiarization trial in Control Condition.

Figure 4a: Experimental Condition

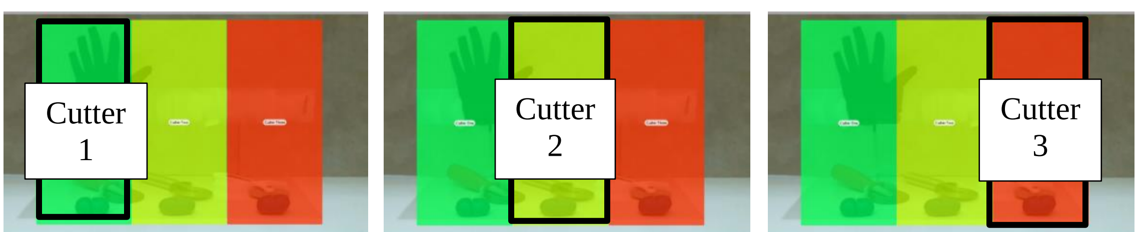
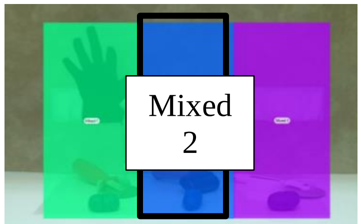


Figure 4. Areas of Interest (AOIs) for Experimental Condition (4a) and Control Condition (4b) Familiarization trials. Figure 4a depicts the AOIs for Experimental Condition, trial 1: Green indicates "Cutter 1" yellow indicates "Cutter 2," and red indicates "Cutter 3." Figure 4b depicts the AOIs for Control Condition, trial 1: Green indicates "Mixed 1" (Cutter), blue indicates "Mixed 2" (Roller), and purple indicates "Mixed 3" (Cutter).

Figure 4 Continued:
Figure 4b: Control Condition



2.5.2 Test Trials

Prior to exporting the looking time data from Tobii Studio, one area of interest (AOI) was created for the initial phase (Figure 5a) and three areas of interest (AOIs) were created for the final phase, based on stimuli presented, to indicate the areas to the left of the screen (i.e., location of roller), center (i.e., location of screen), and right of screen (i.e., location or cutter) (Figure 5b). The left of screen area highlights the area of initial stimulus presentation during the test trial for three seconds (i.e., the roller). The center of the screen represents the occlusion screen where the occlusion event occurred for 2 seconds before proceeding to the Final Phase. The right of the screen includes the area of final stimulus presentation during the test trial (i.e., the cutter) and the area representing an object during the final phase. Scenes were created to indicate times of interest during the initial and final phases of the test trial.

Figure 5a: Initial Phase (9s)

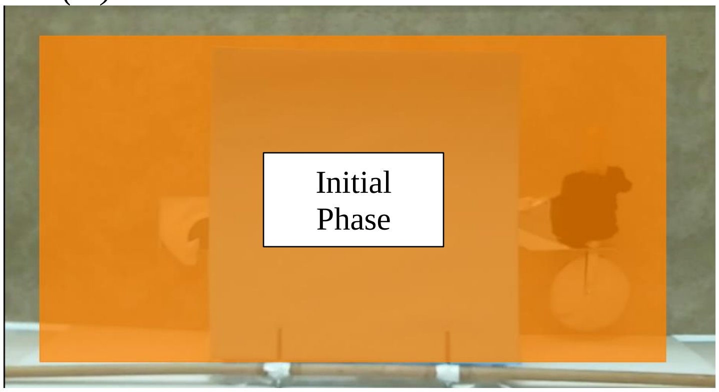


Figure 5b: Final Phase (3s)

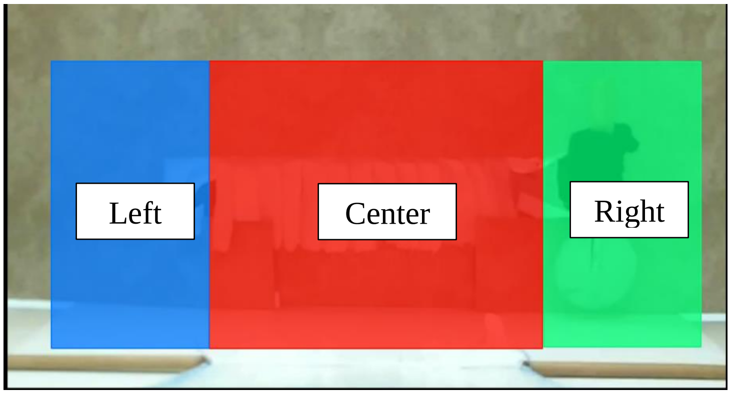


Figure 5. Areas of Interest (AOIs) during test trials. Figure 5a demonstrates the area, or AOI, in which stimulus is present during the Initial Phase. The initial phase includes the pre-occlusion (4s), occlusion, (1s), and post-occlusion (4s). Figure 5b depicts the three AOIs in the final phase. The blue indicates the "Left of Center" AOI. The red indicates the "Center" AOI which is used to calculate the percent-to-center times for the Final Phase. The green indicates the "Right of Center" AOI.

3.0 RESULTS

Preliminary analyses were conducted including gender as a factor. The outcome of these analyses revealed no significant main effects or interactions involving gender on individuation performance. Hence, gender was not included in the analyses reported.

3.1 FAMILIARIZATION AND ANALYSIS

Total fixation duration calculations for each object during the familiarization trials were extracted. In total there was three AOIs. The average looking time across all three AOIs was calculated and used in two 2 x 2 mixed- model analysis (ANOVA) including the familiarization trial averages (within subjects) x condition (between subjects) for both age groups. The main effect of trial x condition for the young age group, aged 3- to 8- months, was not significant, F (1, 81) = 1.107, n.s. Similarly, the main effect of trial x condition for the older age group, aged 12- to 18- months, was not significant, F (1, 87) = 0.286, n.s. These results indicate that infants attended similarly across condition and age group during familiarization trials in both conditions. It is inferred that attention to stimulus is not significantly different across participants and analysis for the test trials proceeded.

3.2 TEST TRIAL ANALYSIS

3.2.1 Initial Phase of Test Trials

As seen in Figure 5a, an AOI was created to evaluate the looking time of infants during the initial phase of the test trials. Total Fixation Duration was extracted during the presentation of stimuli during the initial phase (9 s) for each age group. A repeated measures ANOVA was conducted across the three test trials (within subjects) by condition (between subjects) for both age groups. The main effect of trial x condition for the young age group, aged 3- to 8- months, was not significant, F (2, 162) = 0.385, n.s. Similarly, the main effect of trial x condition for the older age group, aged 12- to 18-months, was not significant, F (2, 174) = 0.953, n.s. These results indicate that infants attended similarly in both conditions and age groups across the three test trials during the initial phase (9 s), suggesting infants in both age groups attended similarly across conditions and trials to the initial phase of the test trials. Therefore, the age differences observed in the final phase can be assumed to result from infants' abilities, or inabilities, to distinguish the objects based on function.

3.2.2 Final Phase of Test Trials

A repeated measure analysis of variance (ANOVA) was performed to evaluate the percent-to-center data for the final phase of each test trial for a total of three trials (within subject) and two conditions (between subjects) within each age group. Percent-to-center looking times were calculated using the formula depicted previously in this report (Formula 1), using three AOIs created to extract total fixation duration looking time for each participant.

For the infants aged 3- to 8- months, the main effect of trial by condition (F(2, 162) = 0.022, n.s.) was not significant. Figure 6 illustrates the younger infants', aged 3- to 8- months, average looking time performance across the three test trials for both conditions. Thus, the younger infants aged 3- to 8- months, did not individuate the two objects shown during the test trials and were unable to individuate based on functional categories demonstrated during the familiarization trials of Experimental Condition.

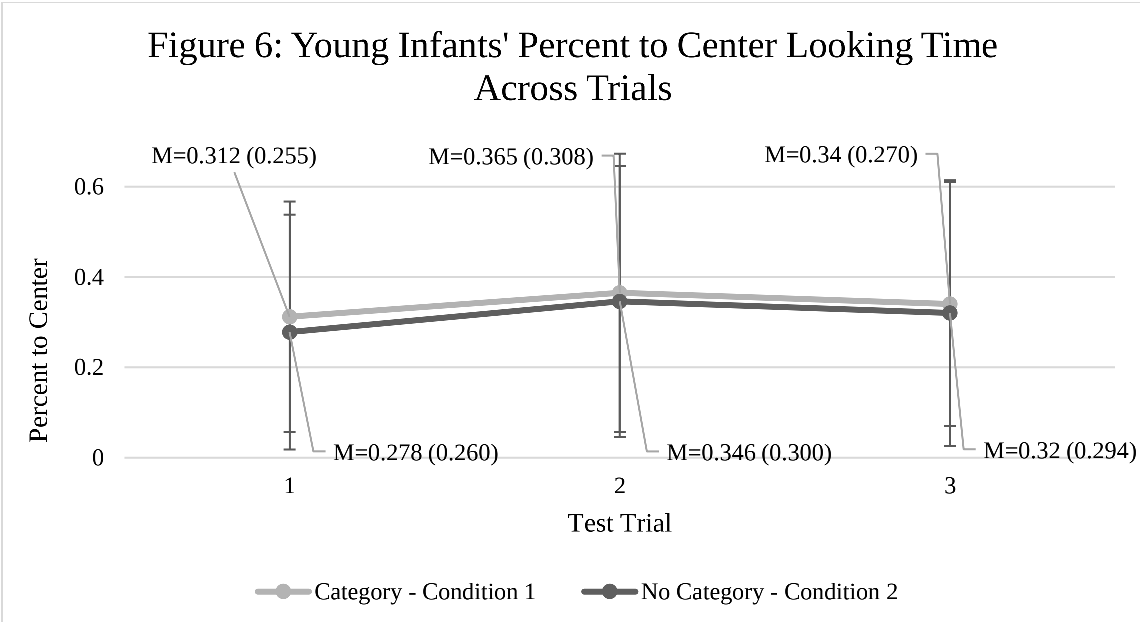


Figure 6: The mean and standard deviation of the younger infants' performances across three test trials for both conditions. No significant differences were found.

The interaction of trial x condition evaluated for the infants aged 12- to 18-months was significant (F(2, 174) = 7.258, p = .001, η_p^2 = 0.077). Figure 7 illustrates the percent-to-center looking times across trials for the infants aged 12- to 18- months in both conditions. An independent samples t-test was conducted comparing the older infants' performance in Experimental Condition (category) and Control Condition (no-category) within each test trial (trials 1-3). There was a significant difference between the scores for the Experimental Condition (M = 0.4303; SD = .244) and the Control Condition (M = 0.2965; SD = .230) during the second test trial; t(87) = 2.596, p = 0.011, *d* = 0.278. In addition, there was also a significant difference in the scores for Experimental (M=0.4827, SD = 0.268) and Control (M = 0.326, SD = 0.171) Conditions during the third test trial; t(87) = 3.099, p =0.002, *d* = 0.332. These results suggest that infants aged 12- to 18- months demonstrated significantly higher percent-to-center looking times during the second and third test trials on the Experimental Condition than on the Control Condition. This indicates that the infants aged 12- to 18- months individuated the objects during the Experimental Condition, but not the Control Condition at a significant level during the second and third test trials.

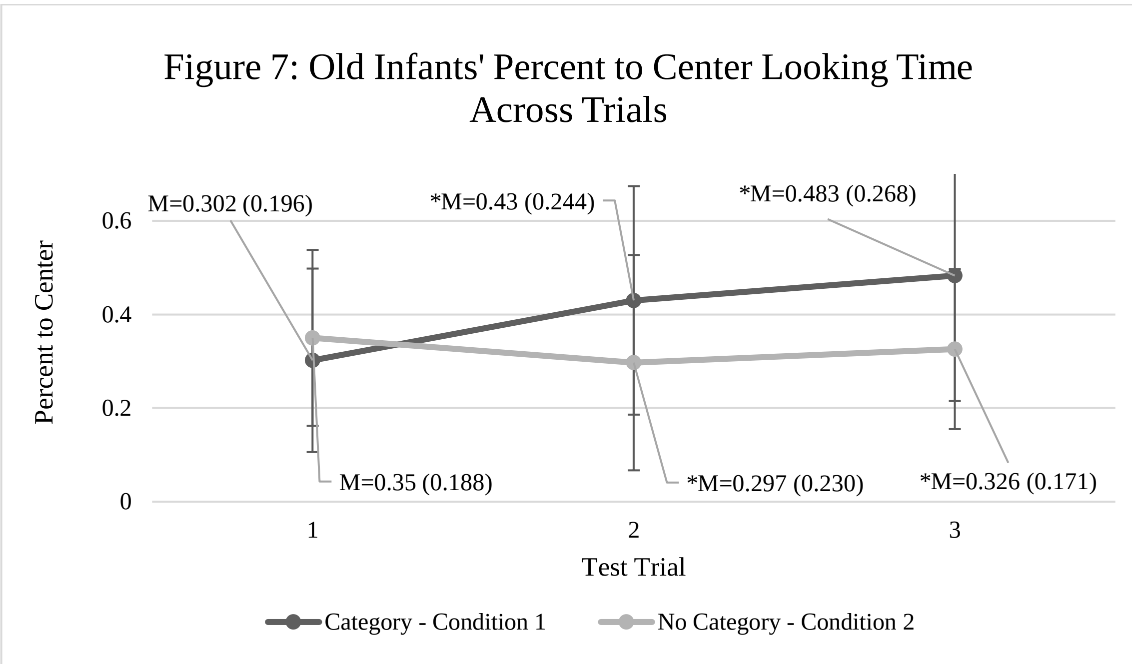


Figure 7: The mean and standard deviation of the older infants' performances across three test trials for both conditions. Significant differences (p<.05) were found between the first and third trial during Experimental Condition (category), suggesting infants aged 12- to 18- months individuated the objects based on functional information.
***Experimental Condition and Control Condition performance were significantly different in trials two (p<0.05) and three (p<.01).**

To evaluate performance across trials within Experimental Condition for infants aged 12- to 18- months, a paired samples t-test was conducted. There was a significant difference between the percent-to-center looking times for Trial 1 (M= 0.302, SD = 0.196) and Trial 2 (M = 0.430, SD = 0.244); t(52) = -3.896, p = 0.00, *d* = -0.540. In addition, a significant difference was found between the percent-to-center looking times for Trial 1 and Trial 3 (M = 0.483, SD = 0.268); t(52) = -4.099, p = 0.00, *d* = -0.568.

Trial 2 and Trial 3 did not indicate a significant difference in percent-to-center looking time, $t(52) = -1.169$, n.s. These results suggest that infants aged 12- to 18- months showed a significant increase in looking time to the center of the platform from Trial 1 to Trial 2, and Trial 1 to Trial 3, suggesting the infants' abilities to individuate increased across trials. Figure 8 illustrates the results of the paired-samples t-test.

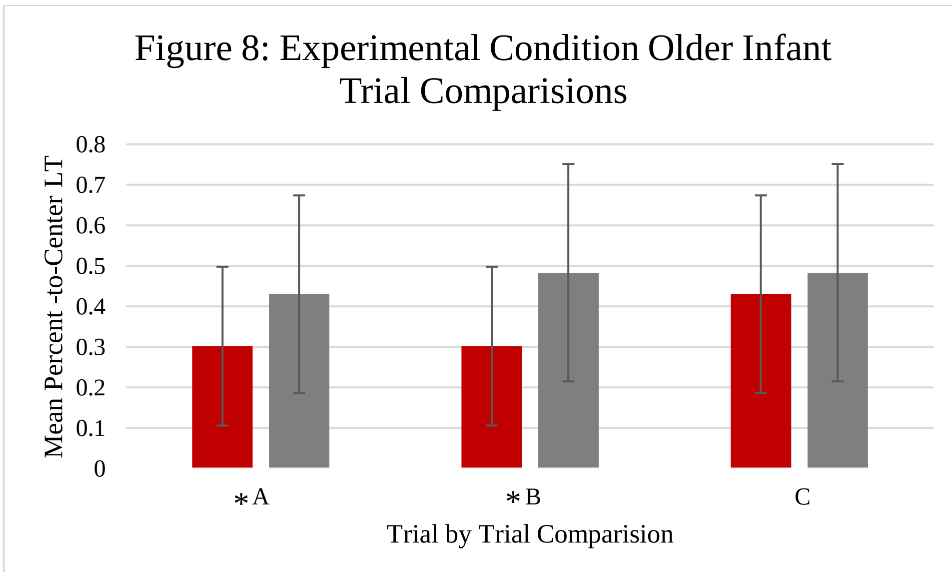


Figure 8: (A) The mean percent-to-center looking time (LT) during Trial 1 was significantly lower than LT in Trial 2 (p<.01). (B) The mean LT during Trial 1 was significantly lower than Trial 3 (p<.01) and (C) There was no significant difference between mean LT in Trial 2 and Trial 3. *Indicates significant differences in mean percent-to-center LT between pairs.

4.0 DISCUSSION AND CONCLUSIONS

Infants aged 12- to 18- months were able to individuate objects based on functional categories over time, while infants aged 3- to 8- months did not demonstrate the ability to individuate objects based on functional categories from which infants observed their function. Previous literature has shown that infants can use features by age 4 months (Woods & Wilcox, 2012), and that infants can individuate object categories by age 4 months (Stavans & Baillargeon, 2016). The results of this project indicate that infants aged 4 months are unable to use functional information to later individuate objects based on function. In addition, the looking time patterns of the older infants aged 12- to 18- months implies that children in this age range need access to stimulus presentation to learn to individuate over time. These findings add to the existing literature stating that infants categorize novel, complex objects based on function around age 12- months (Booth, 2006; Booth & Waxman, 2002; Hernik & Csibra, 2009; Hernik & Csibra, 2015; Träuble & Pauen, 2007), as well as research by Träuble & Pauen (2007) who found that infants aged 11-12 months are able to differentiate functional objects once the object function was demonstrated.

The present study is the first to evaluate infants' abilities to view functional information to facilitate construction of a functional category, then later use this information to individuate objects based on functional kind information. Therefore, it is important to build upon this research and evaluate more specific age ranges at which infants demonstrate the ability to individuate objects based on functional categories, as well as investigate the roles other aspects of development play in object individuation skill acquisition. Two important aspects of development that strongly influence infants' abilities to categorize and individuate objects include language and motor development. The development of both language and motor abilities during infancy is believed to play a vital role in the development of skills necessary to categorize, and then later individuate objects based on functional information.

The influence of language development has long been researched for implications on object categorization, specifically the application of verbal labels, or tags, to environmental stimuli (Ferry, Hespos, & Waxman, 2010; Gliga, Volein, & Csibra, 2010; Xu, Cote, & Baker, 2011). For example, researchers found that infants aged 12- months may use a top-down influence of knowledge when applying labels to visual stimulus, such as kind information (Gliga et al., 2010). Infants ranging in age from 9- to 18- months acquire a vast amount of language skills, spanning from single words to one- and two- word phrases, a majority of which include labels for objects and their functions (e.g., Balaban & Waxman, 1997; Rivera & Zawaydeh, 2007). Typically, children have been found to have acquired at least 30 to 40 words by age 18-months (Rescorla & Mirak, 1997).

At the same time language is developing, children also make significant developmental achievements in motor development, which can directly and indirectly impact early language acquisition. Researchers have emphasized that motor skills significantly change based on individual movement and experiences one has with the environment, therefore, before infants are even able to communicate vocally, motor skills act as a precursor (Iverson, 2010; Taylor, 2010). These motor achievements include both fine and gross motor accomplishments. In addition, beginning in early infancy postural advancements have been shown to influence infant perceptions on environmental objects (Soska & Adolph, 2014; Woods & Wilcox, 2012). Lastly, motor development impacts infants' abilities to manipulate objects in their environment, such as mouthing, bilateral grasps, pincer grasps, and later crawling or walking to explore their environment (Kaufman, Mareschal, & Johnson, 2003; Kingo & Krøjgaard, 2011; McCarty, Clifton, & Collard, 2001; Rakison & Butterworth, 1998; Van de Walle, Carey, & Prevor, 2000). Therefore, future research focused on the influence of both language and motor development is critical to understanding infants' abilities to categorize kind information, then later individuate objects based on this information.

The present study also provides a path for later neuroimaging work, specifically with functional near-infrared spectroscopy (fNIRS) to study the underlying cortical mechanisms and/or the effect of experience on cortical activation. Infant neural development is an essential basis for language, motor, and object individuation research; thus, neuroimaging research is necessary to provide an overall picture of infant development across domains. Research with infants involving fNIRS has grown exponentially in the past decade and continues to show promise in evaluating infant neural networks involved in a variety of developmental areas (Wilcox & Biondi, 2015a; Wilcox, Stubbs, Hirshkowitz, & Boas, 2013).

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