The modulating role of motor action anticipation in relation to visual attention to a scene

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DEDICATION

This thesis is dedicated to my family, every one of them, for all of their love and support in getting me to this point.

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ABSTRACT

This study investigates how visual attention to a scene is modified when the actor has a reaching goal or not. Thirty-six 7-month-olds were recruited, with 18 in a reaching group and 18 in a non-reaching group. Infants in both groups were presented with objects out of their reaching space until they accumulated approximately six seconds of active looking as measured by an eye-tracker. For the infants in the non-reaching group, the trial ended after the six seconds. For the reaching group, the object was then moved into the infants' reaching space where they could reach for it. We were interested in the proportion of looking to the object being presented, the experimenter's hand presenting the object, elsewhere on the scene, and away from the scene. We found that the non-reaching infants spent more time looking away from the scene than the reaching infants ($p < .05$). The reaching infants looked more at the goal object and less at the experimenter's hand than the non-reaching infants ($ps < .05$). In sum, these results suggest that having a reaching goal may drive infants' visual attention more to a scene and toward the actual goal object, while not having an action goal may drive more attention away from the scene and to other areas of the scene (experimenter's hand) besides the object, since they are not planning to act on it.

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CHAPTER I: INTRODUCTION

Vision is an important sensory modality for sighted humans. It is the tool we use to guide the majority of our actions. We use vision constantly to observe our environments and also to plan our interactions with them. On any given day a person will interact with the objects in their surroundings; this requires visual attention to those objects in order to encode them spatially and temporally, followed by forethought of what the person wants to do with the object. This means making predictions about where to bring their arm and hand to contact the object, in addition to how they will manipulate the object once it is in their control. Claxton, Keen, and McCarty (2003) showed that infants make adjustments as they are reaching, for tasks that require a particular type of grasp.

To add another layer, most people interact not just with stationary objects but with other people, and in many cases they interact with objects *with* other people. Object exchange happens all the time, and it requires many skills to be able to navigate such a dynamic environment successfully. Motor skill and predictive ability are both necessary components of object exchange, with vision being the guiding force to make the process work. Object exchange is also a social experience, where one must be able to understand and predict the goal of the other person's action being directed towards them, in addition to being able to predict one's own action and the desired outcome of that action.

For young infants this is especially tricky because they are novices at executing many of the skills required to engage in this object exchange. For example, motor control of the arm and hand to reach for objects is a skill that infants only begin to form around 3-5 months of life (Thelen, Corbetta, Kamm, Spencer, Schneider, & Zernicke, 1993) and they do not master it for some months later. Additionally, visual attention and predictive abilities are crucial for this type

of behavior, which infants do not begin to do until after the 6th month (Falck-Ytter, Gredebäck, & von Hofsten, 2006). A wealth of literature has studied the development of reaching and the coordination required to perform this skill (Thelen, Corbetta, & Spencer, 1996; von Hofsten & Fazel-Zandy, 1984; Lockman, Ashmead, & Bushnell, 1984; Witherington, 2005, to cite a few); and more recently, there has been an increase in research on the aspect of visual attention while infants watch other people perform actions. This work has focused on infants' abilities to predict the goals of the actor's actions. What this work does not tap into is how visual attention is allocated on a scene when infants are engaged in object exchange themselves, compared to watching someone else do it. So, the question remains, where do infants direct their visual attention on a scene when they are planning their own actions compared to simply watching the same scene? As mentioned, both require attention to the scene, but only one requires prediction of the action of the interaction partner, and prediction of their own action outcome. The current study seeks to investigate this gap in the literature.

Visual Attention While Watching Actions of Others

Recently, there has been a growing interest in how infants understand and anticipate actions being performed by *others*, with a focus on visual attention while watching others perform goal-directed actions. In much of this work, infants watch an experimenter perform a goal-directed action either live (Southgate, Johnson, El Karoui, & Csibra, 2010) or on a video recording **(**Cannon, Woodward, Gredebäck, von Hofsten, & Turek, 2012; Hauf, Aschersleben, & Prinz, 2007; Gredebäck, Stasiewicz, Falck-Ytter, Rosander, & von Hofsten, 2009), and infants' eye gaze is measured. In this work the researchers are interested in how the infants track the action being performed, with regards to the target object, the motion of the experimenter, and the goal destination. Predictive eye gazes measure the ability to anticipate the outcome of a goal-

directed action. This measure is calculated by the latency of the fixations to the goal destination of the experimenter's reach, compared to the latency of fixations to the actual object or hand of the experimenter being moved there.

Functionality of Actions: Natural vs. Unnatural Contexts. Falck-Ytter (2012) proposed two hypotheses for understanding actions—in the direct-matching hypothesis, the configuration of the hand affects where gaze is directed. In the inference account, predictive eye movements are contingent on that the observer understands the intention of an agent is to achieve a goal. Falck-Ytter asserts that humans are better able to predict the action goals of humans compared to non-human agents because we perform those actions ourselves, but in either case it helps if we understand that the agents are performing a goal-directed action.

Falck-Ytter, et al. (2006) showed that when watching a human agent perform a reaching action compared to a non-human agent, 6-month-olds were able to *track* the action, but not *predict* the outcome of it, regardless of agency. Twelve-month-olds, however, showed predictive abilities similar to adults—still, both infants and adults only showed predictive gazes in the human agent condition. This study shows that infants can use vision to anticipate the outcome of another person's goal-directed action. The importance of human agency in infant action understanding has been further supported by other studies (e.g., Cannon & Woodward, 2012). These studies underlie the notion that the more naturalistic a task is the more attentive the infants are and the better they are at anticipating the outcome of the action.

Cannon and Woodward (2012) investigated whether context or location of a goal-directed action drives looking behavior while viewing the action, and their results also provided further evidence on the importance of human agency. They measured looking behavior in 11-month-olds while watching either a human hand or a mechanical claw reach for an object when

two objects were present. Then, the locations of the objects were switched and the agent (human or mechanical) reached at midline. The experimenters were interested in where the infants looked when the agent reached at midline, either to the original target object in a new location or to the original location. They found that infants used predictive looking based on context, not location; namely, when the human hand reached at midline, the infants looked to the target object and not the original location. In contrast, when the mechanical claw reached at midline, they looked at the original location. Ultimately, the infants were only able to anticipate the goal of the action to the original target object when the agent was a human hand. This supports Falck-Ytter's (2012) assertion that human infants are better able to predict goal-directed actions of other humans, and that this helps infants understand the goal-directed context of the action. The infants could not attribute the behavior of the claw as goal-directed, and this inhibited their ability to predict the action outcome; whereas for the human action they were able to do so.

In addition to human agency, functionality of an action enhances its predictive value for action outcome. Two studies using different measures showed that infants were better able to both predict and process actions that they understood as functional reaching behaviors compared to actions that would not be functional for reaching. First, Gredebäck et al. (2009) measured predictive looking behavior of 10- and 14-month-olds in three conditions. In one condition, infants watched an experimenter move objects by hand from one board to another. In a second condition, they watched the experimenter move objects from a board and place them into a container. In a third condition, the experimenter used a closed fist and moved it from one board to another, mimicking a reaching action, yet with a non-functional hand configuration. Overall, the 14-month-olds were better at anticipating the goal of the action than the 10-month-olds; however, both groups were better at anticipating when the hand performed the actions with a

natural reach compared to a closed fist. This work shows that the infants were able to discriminate that one action was more functional for the task than another, which was exhibited by the success at predicting the outcome of the action.

Brain activity has also been used as a measure of action understanding. Southgate et al. (2010) measured infants' brain activity in motor areas while watching an experimenter perform a reaching task. The experimenter used a grasping configuration to either reach behind an occluder, or reach with no occluder but no target object present. The experimenter also reached with an unnatural backward hand movement with both conditions. They saw brain activity in motor areas only when the experimenter reached with a natural grasping configuration behind an occluder, compared to reaching with either an incomplete or unnatural motor action. The fact that the motor brain areas were only active while the experimenter portrayed a natural or functional grasp suggests that the infants were able to perceive a motor outcome in this condition only.

Familiarity of actions. Another question researchers have investigated pertaining to action understanding is whether infants are better able to anticipate actions of others when they are watching an action they are able to perform themselves. Cannon et al. (2012) measured this in two conditions, performing the behavior then observing the behavior performed by an experimenter, or the reverse. Observation first infants showed more predictive gazes overall; however, behavior first infants showed increasing predictive gazes depending on how much they interacted with the objects and performed the task. This second finding suggests that the more engagement with the activity, the more visual attention was paid to it.

Hauf et al. (2007) investigated a similar question about the effect of familiarity with an action on predictive ability in four experiments. They aimed to determine whether first

performing an action themselves would influence infants' interest in watching others perform the same action. In the first experiment, 7-, 9-, and 11-month-old infants first played with a toy, then watched side-by-side videos of two experimenters playing either with the same toy or a different toy. Nine and 11-month-olds looked at the video of the familiar toy longer than the video of the unfamiliar toy, while 7-month-olds showed no difference. This would suggest that if infants played with the familiar toy before observing the action, this influenced their visual attention to the video with the same toy. In a follow-up study, the experimenters in the videos looked at the objects but did not interact with them. As the 7-month-olds showed no differences before, they were not tested in this study. Hauf et al. found no differences in looking to either video in this study, supporting the importance of viewing others *actions* in action perception. In a third study, two videos of the objects close-up with no actors in the videos were played simultaneously. There were no differences in looking times in this study. In a final study, rather than let the infants play with the toy before watching the videos, an experimenter played with the object in front of the infant before showing the two videos used in Experiment 1. Again, they saw no differences. Overall these studies support the idea that interest (i.e., visual attention) in others' actions is influenced by agentive experience.

In contrast to many of the above studies Reddy, Markova, and Wallot (2013) have shown that infants as young as 2-4 months can anticipate actions that are being performed in reference to them. When mothers approached their infants to pick them up, the infants made postural adjustments in preparation of the action and looked at the mothers' arms and hands. This shows that these young infants were able to predict the action that their mothers were acting upon them, indicating that even these very young infants show anticipation of goal-directed actions. However, the only thing that this and the previously discussed research tells us is how infants use

visual attention when watching others perform actions. None of this literature addresses how visual attention is directed at a scene when infants are the actors themselves—this is the focus of the current study.

Visual Attention to Scenes

All of the above studies looked at visual attention as a measure of anticipation or predictive looking, but other work has shown that simple aspects of the visual scene can influence where visual attention is directed. For example, Cohen (1972) looked at how properties such as size and number of stimulus elements influence what he called *attention-getting* and *attention-holding* processes. Attention-getting refers to latency in orienting to a stimulus, while attention-holding refers to duration of individual fixations. In this study he found that size of the stimulus affected latency in turning to look at it, and complexity of the stimulus affected fixation durations, or attention-holding.

Complexity has been further explored by other researchers as a key component in attracting or deterring visual attention from a scene. Fantz and Fagan (1975) made the distinction that size is a separate factor from complexity, and while size is more influential at younger ages, after about nine weeks (Ruff & Turkewitz, 1975; Ruff & Turkewitz, 1979) complexity becomes more influential. Complexity of a stimulus is thought to include aspects of a stimulus like the number of details, which hold more information about the stimulus than size alone (Fantz & Fagan, 1975).

Cohen (1972) found that infants tend to look longer at more complex stimuli and are quicker to orient to stimuli of moderate complexity. This suggests that complexity of a stimulus influences the amount of visual attention that will be directed toward it. Cohen's finding was more recently replicated and extended by Kidd, Piantadosi, and Aslin (2012), who found that the

complexity of a scene influences visual engagement with a task, and that there is an optimal level of complexity which elicits the most visual attention to the scene. By manipulating the complexity of a 2-dimensional scene, Kidd et al. found that infants were less engaged when the scene was too high or low in complexity, but when the level of complexity was moderate, the infants remained attentive. Both Cohen's and Kidd et al.'s findings about stimulus and scene complexity are informative for the current study. The stimulus objects that will be presented vary in complexity based on the number of distinctive object parts; so one question is whether this in itself will elicit differential visual attention to the scene. However, across groups, scene complexity will be equal; thus, a second question is whether motor interaction with objects in the visually perceived scene, compared to a similar condition where no motor interaction is solicited, will impact the distribution of infant visual attention on a scene.

Corbetta, Thurman, Wiener, Guan, and Williams (2014) investigated how early hand-eye coordination developed in a longitudinal study, and found that when infants had a reaching goal they fixated the part of the object with which they ultimately made first contact. While this study was very preliminary with a small sample size, it suggests that having an action goal elicits focused visual attention on the target of the goal. So a question that still remains is whether having an action goal drives the same focused visual attention on the scene as a whole, and whether a lack of an action goal drives visual attention away from the scene. In the current study, this question was operationalized by having infants in one group reach for objects (reaching group with action goal) and in another group, the opportunity to reach for the objects was not offered (non-reaching group with no action goal). However, both groups were exposed to the same scene before reaching was offered in the action goal group.

Current Study

The current study builds from each of the previously discussed studies in several ways. First and most importantly, in this study the infants in the reaching group *were* the actors performing a reaching task, rather than watching someone else perform an action. Much of the previous work has measured visual attention while infants watched someone else perform a goal-directed action. In this study, I measured visual attention as a function of whether the infants were offered the opportunity to act on objects following exposure to the scene or not. Additionally, many studies measuring visual attention on a scene use habituation paradigms where infants watch 2-dimensional screens and are never offered the chance to interact with the scene. These studies do measure visual attention but not in the context of infant performance because in many of those studies the infants were never asked to manually do anything. My study, in contrast, used a 3-dimensional scene, where infants in one group were encouraged to interact with an object in the scene following a period measuring visual attention to that same object. In sum, I asked how infants visually attended to that object and scene depending on whether they were given the opportunity to interact with it or not.

In the current study I presented objects out of reach to two cohorts of 7-month-olds while using an eye-tracker to measure eye gaze patterns; in the "reaching" group I allowed them to subsequently reach for the object, while in the "non-reaching" group I did not offer them that opportunity. Seven-month-olds were targeted because it is known from previous research that they have both ample reaching experience (Thelen et al., 1993; Corbetta et al., 2014) and the ability to predict future action goals (Reddy et al., 2013; von Hofsten & Fazel-Zandy, 1984) when they are actors in the context.

The task chosen aimed to incorporate many of the components that would occur in a natural object exchange and required that the infants coordinated the same skills that would be needed in such an interaction. Thus, in my task, the object was held out of reach by a visible human hand to incorporate the social aspect of interacting with a human. Second, after the period of observing the object out of reach, infants in the reaching group needed to anticipate that the object was going to be moved toward them and that they would have the opportunity to reach for it. In the non-reaching group, I measured vision of the object in the scene while held out of reach, without offering the opportunity to reach afterward. The question at hand was whether looking at the scene, measured by eye-tracking would be different when infants were given the opportunity to plan an action versus just watching the scene.

Hypotheses. Based on the research from Cohen (1972) and Kidd et al. (2012) about the effect of task complexity on visual attention and engagement, I predicted that the infants with a reaching goal would be more visually attentive to the scene overall than the non-reaching infants. Here I make the hypothesis that between scenes of equivalent complexity, knowledge of a future action could suffice to drive attention to or away from the scene.

In terms of visual attention on the scene, infants in the reaching group should spend more time looking at the object compared to other areas of the scene, including the experimenter's hand holding the object, compared to infants who will not be reaching. This is based on the idea that when infants have an action goal in mind, the outcome—in this case the target object—should guide the infants' visual attention on the scene. Similarly, while the non-reaching infants should spend more of their looking away from the object, they may look more at the experimenter's hand than the reaching group because in the absence of an action goal, the social aspect of the human hand could draw more focus.

Lastly, I was interested in the distribution of visual attention on each object itself. Research has shown that infants show a visual preference to the larger stimuli (Fantz & Fagan, 1975; Newman, Atkinson, & Braddick, 2001; Guan & Corbetta, 2012), which is also the part with which they tend to make first contact (Corbetta et al, 2014). I expected the reaching infants to follow this pattern of focused object looking as they were planning to act on the object, while perhaps the non-reaching infants would show a more distributed pattern of looking on the objects because they were not planning an action and, thus, their visual attention would be less drawn to any particular part of the object.

CHAPTER II: METHOD

Participants

A total of 41 7-month-old infants (± 1 week, *M* = 30.62 weeks) were recruited from the Greater Knoxville area in Tennessee, US to participate in this study. From this sample, five infants were excluded due to fussiness (*n* = 1), inability to calibrate the eye-tracker (*n* = 2), poor calibration resulting in unusable data (*n* = 1), or not enough data (*n* = 1). In the final sample, 36 infants were included, with 18 each in the reaching and non-reaching groups. Demographic information for the infants was not recorded, but racial background of the infant participants' parents were as follows: Mothers were 91.67 % White/Caucasian, 2.8 % Hispanic/Latina, 2.8 % Asian, and 2.8 % unknown. Fathers were 83.33 % White/Caucasian, 5.56 % Hispanic/Latino, 5.56 % unknown, 2.8 % Black/African-American, and 2.8 % Asian.

Participants were contacted via phone call by the experimenter using information provided by caregivers in response to an initial interest letter regarding developmental research at The University of Tennessee, Knoxville. Informed consent was collected from all participants. All participants were given a certificate of the infants 'participation, and a photo from the appointment.

Materials

Infants were seated in a specially designed seat reclined 10 degrees from vertical, secured with a foam strap around the trunk. This seat allowed for full range arm and leg movement, while securing infants in front of the presentation area. A small pillow was located behind the head. The infant seat was placed in front of a theater so that the distance from the eye-tracker to the infant's eyes was 60 centimeters.

The set-up for the study (see Figure 1 in Appendix) included a tri-fold black wooden theater to minimize ambient distractions. The theater was placed over a small wooden table with a 15-inch x 17.5-inch opening for the presentation area. A 17-inch flat screen Dell computer monitor located on a moveable arm was used for calibration of the eye-tracker. This monitor was placed in the theater's presentation area for calibration and then removed for the remainder of the session. When the monitor was removed, a black curtain at the front of the presentation area was closed, and a black curtain at the rear was put in place to provide a consistent black background to the presentation area. The front curtain opened and closed at the beginning and end of trials via a string and pulley system, and the rear curtain, which was always closed, also helped to conceal the experimenter during presentation.

A Tobii x50 remote eye-tracker (Tobii Technology, Inc., Daynerd, Sweden) was placed on the edge of the small table and at the bottom of the presentation area. The eye-tracker was set at an angle between 60 degrees and 70 degrees based on the heights of the infants, in order to capture a steady eye signal from the infants.

A video camera was located behind the infants to record the scene on which the eye gaze data were mapped. The eye-tracker was run through Tobii Studio software (v. 2.0.8). A webcam was also used to record the infants' faces, which allowed the experimenters to track when the infants were looking at the scene versus away. In cases of no fixations on the scene, it allowed the experimenters to determine if there was a loss of signal or simply no looking at the scene.

Four different types of objects were presented to the infants (see Figure 2 in Appendix), including drumsticks (13.5cm long x 1cm wide, with one 5cm diameter sphere attached to one end), dumbbell-shaped objects (made of 8.5cm long x 1cm wide rod with two 5cm diameter spheres, attached on either end), plain rods (8.5cm long x 1cm wide), and plastic cups with one

handle or two handles (5 x 5cm with 3 x 1.5cm handle(s)). The first three objects were wooden, painted in different solid, vibrant colors using non-toxic acrylic paint, and sealed with a clear non-toxic gloss. The cups were made out of plastic. The objects were designed to be large enough to elicit visual exploration and allow the identification of scanning patterns, yet small enough for the infants to easily grasp with their hands.

Procedure

Upon arrival to the lab, caregivers were first brought over to the set up while Experimenter 1 explained the procedure, and were encouraged to ask any questions. Then, informed consent was collected. Finally, Experimenter 1 took the caregivers and infants over to the setup to fasten the infant in the seat.

While the infants were fastened in the seat and in preparation for calibration, a Sesame Street video (www.sesamestreet.org) was played on the monitor to occupy the infants' attention and direct it to the computer monitor. This allowed Experimenter 1 to make sure she had a steady eye signal and to make adjustments to the angle of the eye-tracker or distance away from the infants, if necessary.

When a steady signal was achieved, calibration was initiated. Infants were required to fixate on five different points on the screen, each corner and the center, for a few seconds. At each point there was a moving cartoon image associated with a sound. Experimenter 1 sat by the infants to direct their attention to the different points, while Experimenter 2 controlled the calibration from a computer in an adjacent room. This experimenter also controlled the eye-tracker recordings for each trial, while Experimenter 1 presented the objects to the infants.

The experimenters aimed to get accurate signals at all five points in both eyes. In some cases, they were unable to get any signal at one or more particular points. If this occurred

repeatedly and they were unable to acquire a signal in a short enough time, they accepted the calibration with a minimum of three accurate points because they did not want to lose attention or patience from the infants (n = 4). Recordings with three points had just as accurate eye-tracking signals as recordings with four or five points. After calibration the monitor was removed from the presentation area and the curtains were put in place. Then, the session could begin.

Each of the four objects was presented in horizontal and vertical orientations (with exception of the cups) two times, for a total of 22 trials. If the infants became fussy or no looking data was being captured, the session was stopped before the completion of all trials. Experimenter 1 positioned the object in between the two curtains, in the center of the presentation area, and signaled Experimenter 2 to begin the recording, by saying, "we're ready." Experimenter 2 would then signal Experimenter 1 that the recording had started by ringing a bell. After hearing the bell, Experimenter 1 would open the curtain to begin the trial.

Objects were held steadily in place to capture an estimated accumulation of six seconds of looking at the object. This approximated equal looking time to the object in both groups. In some cases the objects were held out longer than six seconds to ensure that enough active looking was captured. For comparable analysis, only the first six seconds of trials were included for all analyses.

In the non-reaching group, when approximately six seconds of active looking was achieved, Experimenter 1 closed the front curtain, which signaled Experimenter 2 to stop the eye-tracker recording. Then, Experimenter 1 prepared the object for the next trial. In the reaching group, after the six seconds was collected, Experimenter 1 brought the object forward into the infants' reaching spaces, at midline, to allow the infants to reach for and grasp the object. After the infants either had control of the object, or dropped it, Experimenter 2 ended the recording.

The caregivers were asked to retrieve the object from their infants and place it into a bucket outside of the infants' views. When the infant's hands were free and the previous object was out of sight, Experimenter 1 prepared for the next trial as above.

Objects were presented in a random order for each infant, based on a protocol generated in Matlab (The MathWorks, Inc., Natick, MA, USA), however, with the exception that the same object of the same orientation was never presented twice in a row.

Coding and Analysis

In order to obtain the accumulated six seconds of active looking, Experimenter 1 had to estimate time during object presentations. Due to human error, some trials had more and others had less than six seconds of active looking. So, for all analyses only up to the first six seconds of active looking for all trials for all infants was included. All trials were coded using the behavioral analysis software The Observer XT, v. 9.0 (Noldus Information Technology, Inc., VA, USA). This software allowed for frame-by-frame coding of the eye-tracking videos. Areas of interest on the presentation area were defined, and then all fixation points visible on the scene were coded (see Figure 3 in Appendix). The coding scheme allowed the experimenters to code the exact location of the fixations while the software calculated the duration of fixations and number of transitions, or looks, to each area of interest. To maximize accuracy, they used the very center of each fixation point as a marker of which area of interest to code.

The Areas of Interest (AOIs) included fixations on the object, the experimenter's hand, and elsewhere on the scene. The code of elsewhere included any fixation point visible on the presentation area that was not located on the object or experimenter's hand. Further, each object was broken into three or more areas of interest. The drumstick object included end rod, middle rod, and sphere (top, bottom, left, or right). The dumbbell included top or left sphere, middle rod,

and right or bottom sphere. The plain rod included top or left rod end, middle rod, and bottom or right rod end. The cup was divided by body and handles, with body including top, middle, and bottom AOIs, and left or right handle. For analyses, the left and top ends of the dumbbell and plain rod were collapsed, as well as the right and bottom ends, while for the cups, the cup body AOIs were collapsed and both cup handle AOIs were collapsed. Previous work by Corbetta et al. (2014) used this same method for analysis after finding that separating those AOIs showed no differences than when they were collapsed. One experimenter coded all of the trials and a second independent coder coded a random 20% of trials in each group. Interrater reliability was 94% proportion of agreement for all trials combined. Any discrepancies were discussed until an agreement was made.

Additionally, the experimenters coded how often and for how long the infants looked away from the scene. A code of "look away" was used when there was no eye signal on the scene and the infants' eyes were clearly not on the presentation area, as determined by the webcam view. In any case where coders were unsure if the infants were looking away, when there was no eye signal but it was too difficult for the coder to tell if the infants' eyes were still looking at the scene, if the signal was lost or if the infants' eyes were looking away but very slightly, this was not included in the coding. In the cases where there was no signal for less than five frames before it reappeared, this was not included either.

The "time to first fixation" was also coded. This is a measure of the length of time from the start of the trial to the first fixation point that appears on the scene. Interrater reliability for time to first fixation coding was 99% proportion of agreement for all trials combined, while reliability for look away coding was 89% proportion of agreement for all trials combined. Any discrepancies were discussed until an agreement was made.

Several analyses were conducted on these data. The independent variable for this project was the condition, reaching or no reaching. Many analyses included the dependent variable of looking durations to each AOI. Proportions of looking to each overall AOI out of the total looking at the scene and proportions of looking at each object AOI out of total looking to the object were calculated. The number of looks between each AOI was used for a number of analyses. This variable refers to the number of times the infants focused their visual attention on each area of interest, regardless of how many fixations occurred within each look. For example, infants could look at an object and have multiple fixations but this would only be considered one look; then, when they transitioned their visual attention elsewhere on the scene then transitioned back on the object, this would be a second look to the object. Duration of looks away from the scene, as well as the number of times the infants looked away from the scene, was used for additional analyses. All of these variables were compared both within and between groups.

Lastly, time to first fixation was compared between groups, including latencies to the first scene fixation, the first object fixation, and the first fixation to the experimenter's hand. One-way and repeated measures ANOVAs were performed on data that were normally distributed, while non-parametric analyses were used for data that were not normally distributed. Friedman and Wilcoxon tests were used for within group data, and Mann-Whitney tests were used for between group data.

CHAPTER III: RESULTS

From the final sample for analysis, the average number of trials collected per infant was 20.22 (*SD* = 2.86). To see if there was a difference in trial length between the groups a one-way ANOVA was performed on trial duration. This test was significant ($F(1, 35) = 10.66$, $p = .003$) such that trials for the non-reaching group (*M* = 16.03 sec, *SD* = 6.09) were longer than trials for the reaching group (*M* = 10.73 sec, *SD* = 3.22). The difference in trial length between groups is indicative that the object had to be held out for longer in the non-reaching group in order to accrue six seconds of active looking. Despite controlling for a maximum of six seconds of active looking in the coding, a non-parametric test revealed a small, but significant difference in active looking between the two groups (Mann-Whitney, $p = .001$) such that the reaching group had less active looking at the scene overall (*Mdn* = 5.02 sec) than the non-reaching group (*Mdn* = 5.67 sec). This suggests that in the reaching group there were more trials where infants did not accumulate six seconds of active looking. It is probable that more infants did achieve six seconds of active looking in the non-reaching group due to the fact that the object was held out for longer.

Analysis of Visual Attention to and away from the Scene

As a measure of the engagement with the task we coded both the durations and number of times attention was directed away from the scene between groups and within group among the different objects that were presented.

Time to First Scene Fixation. This analysis looked at the latency from the start of the trial to first fixation on the scene to identify how long it took for the infants in both groups to orient their visual attention to the scene. A non-parametric test revealed that there were no differences between groups (Mann-Whitney, $p = .48$) in terms of how long it took from the start

of the trial to the first fixation on the scene (Non-reaching *Mdn* = 1.23 sec, Reaching *Mdn* = .74 sec). This was also true when looking at the time to first fixation by individual objects (Mann-Whitneys, all *p*s > .05).

Time to First Fixation on Object and Experimenter's Hand. Further, I looked at the latencies from the start of the trial to the first fixation on the object versus the first fixation on the hand. These may or may not have been the first fixations on the scene. There were a number of analyses I was interested in doing with these measures, including the proportion of time for which the object, experimenter's hand, or elsewhere was the first AOI being fixated, the sequence in which fixations to the object and the experimenter's hand occurred, and the average latencies to the first fixation on each the object and the experimenter's hand.

Proportion of Time for which Object, Experimenter's Hand, or Elsewhere were First Scene Fixation. This analysis looked at how frequently out of the total number of trials per baby each area of interest was the first scene fixation. A Group (2) x AOI (3) repeated measures ANOVA revealed a main effect of AOI ($F(1, 33) = 126.92$, $p < .001$; see Figure 4 in Appendix), such that elsewhere was predominantly the first scene fixation (Non-reaching *M* = .61%, *SD* = .15, Reaching *M* = .65%, *SD* = .10) more than the object (Non-reaching *M* = .23%, *SD* = .11, Reaching *M* = .25%, *SD* = .14, $p < .001$) or the experimenter's hand (Non-reaching *M* = .16%, *SD* = .10, Reaching *M* = .10%, *SD* = .09, $p < .001$). There was no effect of group.

Sequence in which Fixations to the Object and Experimenter's Hand Occurred. This analysis looked at the order of first fixations to the object and experimenter's hand to see which typically came first. For this analysis I looked at whether the object and experimenter's hand were the first scene fixation, and if not, whether they came second or third in sequence after the first scene fixation. Thus, I looked at the average rank order in the sequence for each of the two

areas of interest. A Group (2) x AOI (2) repeated measures ANOVA revealed a main effect of AOI ($F(1, 34) = 4.94$, $p = .033$), such that the object was more frequently fixated earlier in the sequence (Non-reaching $M = 1.97$, $SD = .22$, Reaching $M = 1.93$, $SD = .29$) than the experimenter's hand (Non-reaching $M = 2.10$, $SD = .25$, Reaching $M = 2.04$, $SD = .34$). There was no significant group effect or interaction.

Additionally, I was interested in whether there was a difference between groups in the number of trials where the infants actually fixated the object and experimenter's hand. A Group (2) x AOI (2) repeated measures ANOVA revealed both main effects of AOI and group, as well as an AOI x group interaction. The significant main effect of AOI ($F(1, 34) = 67.93$, $p < .001$) indicates that there was a greater proportion of trials with looking to the object (Non-reaching $M = .93\%$, $SD = .10$, Reaching $M = .92\%$, $SD = .09$) than there were trials with looking to the experimenter's hand (Non-reaching $M = .78\%$, $SD = .12$, Reaching $M = .63\%$, $SD = .18$). The significant main effect of group ($F(1, 35) = 5.02$, $p = .032$) indicated that overall, the non-reaching group had more trials with looking to both the object and experimenter's hand ($M = .85$, $SD = .02$) than the reaching group ($M = .78$, $SD = .02$). For the reaching group, there was a greater proportion of trials with looking to the object compared to the experimenter's hand but for the non-reaching group this proportion was about the same, as indicated by the significant interaction ($F(1, 34) = 6.56$, $p = .015$).

Average Latency to First Fixation on Object and Experimenter's Hand. This analysis looked at the average duration or latency from the start of the trial to the first fixation on the object or the experimenter's hand. Results were compared both within and between groups. Non-parametric tests revealed that for both groups there was a shorter latency to the first fixation on the object (Non-reaching $Mdn = 2.00$ sec, Reaching $Mdn = 1.56$ sec) than there was to the first

fixation on the experimenter's hand (Non-reaching *Mdn* = 3.52 sec, Reaching *Mdn* = 3.49 sec; Mann-Whitney, all *p*s < .002; see Figure 5 in Appendix). However, between groups there were no significant differences in latencies to first fixations on the object or experimenter's hand (Wilcoxons, all *p*s > .05).

Summary of First Fixations. Overall, these analyses show very similar findings. For both groups, fixations to the object came before fixations to the experimenter's hand. However, in terms of scene fixations, elsewhere was predominantly the first scene fixation. The non-reaching group had more trials of looking to both the object and experimenter's hand overall than the reaching group, although for the reaching group, specifically, there were more trials of looking to the object than the experimenter's hand. Lastly, there were no differences in latency from start of trial to the first scene fixation, regardless of where the first scene fixation was.

Durations of Looking Away from the Scene. The purpose of this analysis was to look at the differences in visual engagement with the scene overall between the two groups. A one-way ANOVA of the actual durations was used to test whether there was a difference in the overall duration of looking away from the scene between groups (see Figure 6 in Appendix). This test revealed that the non-reaching group (*M* = 7.89 sec, *SD* = 4.96) had significantly longer durations of looking away from the scene ($F(1, 35) = 9.45$, $p = .003$) than the reaching group (*M* = 3.81 sec, *SD* = 2.66). There were no within group differences for the look away duration between objects ($F(3, 35) = 1.49$, $p = .227$). When all of these data were normalized out of the trial duration, however, the non-reaching group no longer looked away more, proportionately, as there were no between group differences. However, a Group (2) x Object (4) repeated measures ANOVA showed that there was an effect of object ($F(1, 35) = 3.68$, $p = .018$), such that the plain rod was the object that elicited the most looking away (Non-reaching *M* = .35%, *SD* = .17,

Reaching *M* = .23%, *SD* = .17) and the dumbbell was the object that elicited the least looking away (Non-reaching *M* = .30%, *SD* = .17, Reaching *M* = .23%, *SD* = .17).

Number of Times Infants Looked Away from the Scene. In addition to the duration of looking away from the scene, I analyzed the number of times the infants looked away from the scene in each group. A one-way ANOVA revealed a marginally significant group difference in the number of times the infants looked away from the scene ($F(1, 35) = 3.64$, $p = .065$; see Figure 7 in Appendix), such that the non-reaching group (*M* = 2.00, *SD* = .72) tended to look away a greater number of times than the reaching group (*M* = 1.48, *SD* = .79). I also looked at this difference for each object and there were no significant within group effects or interactions for this variable ($F(3, 35) = .68$, $p = .55$).

Comparison of Look Away Variables Over the Course of Experimental Session. I was interested in whether this variable of inattention changed over the course of each infant's experimental session, so I took the first and last 33% of trials from each infant and compared the actual durations of looking away from the scene, as well as the number of times the infants looked away. These variables were compared within and between groups. Wilcoxon analyses revealed that for both groups there were significantly longer durations of looking away (all *p*s < .01) in the latter third of the session (Non-reaching *Mdn* = 11.64 sec, Reaching *Mdn* = 4.29 sec; see Figure 8 in Appendix) compared to the earlier third of the session (Non-reaching *Mdn* = 2.94 sec, Reaching *Mdn* = 2.73 sec). However, while there were no between group differences in the early third of trials (Mann-Whitney, $p = .44$), there was a significant between group difference in the duration of looking away in the latter third of trials (Mann-Whitney, $p = .007$), such that the non-reaching group looked away for longer durations than the reaching group.

Additionally, there was a significantly greater number of times of looking away from the scene (Wilcoxons, all *p*s < .01) in the latter third of trials (Non-reaching *Mdn* = 2.24 sec, Reaching *Mdn* = 1.79 sec; see Figure 9 in Appendix) for both groups compared to the earlier third of trials (Non-reaching *Mdn* = 1.21 sec, Reaching *Mdn* = 1.29 sec). Non-parametric analyses between groups revealed no group differences for this variable (Mann-Whitneys, all *p*s > .05).

Visual Engagement with the Task. To look at the allocation of visual attention on the scene and away from the scene, I calculated proportions of looking duration at the object, the experimenter's hand, elsewhere on the scene, as well as the proportion of looking away from the out of the total trial duration. Non-parametric tests revealed that between groups there were marginal differences in looking at the object (Mann-Whitney, $p = .059$; see Figures 10 and 11 in Appendix), the experimenter's hand ($p = .051$), and looking away ($p = .055$), but no difference in the proportion of looking elsewhere. Wilcoxon tests also revealed within group differences for all area of interest variables in the non-reaching group (all *p*s < .05; see Table 1 in Appendix), except for the comparison between looking at the object and elsewhere. For the reaching group, proportions of looking at all variables were significantly different than the proportion of looking at the experimenter's hand (all *p*s < .01), but there were no other within group differences.

This analysis was additionally performed for each object individually to compare visual attention on the scene for each object. A Mann-Whitney test revealed no significant group differences (see Figure 12 in Appendix). Within group differences are displayed in Table 2 (in Appendix). The main within group differences of note are that for all objects and both groups, except for one case, there was more looking at the object, elsewhere, and looking away than at the experimenter's hand. The one instance where this was not true was that in the non-reaching

group for the plain rod there was no difference in looking between the object and the experimenter's hand. The case of less looking at the plain rod will be addressed in more detail later.

Summary. Overall, these results showed that the non-reaching infants looked away from the scene for longer durations than the reaching infants. All infants looked away from the scene more at the end of sessions compared to the beginning. Lastly, when comparing all scene areas of interest, there was marginally more looking to the object in the reaching group compared to the non-reaching group, and marginally more looking to the experimenter's hand and looking away in the non-reaching group compared to the reaching group.

Analysis of Visual Attention During Active Looking

Visual Engagement with the Scene. Next, I was interested in how visual attention was allocated on the scene when just taking into consideration the active looking. So for this analysis, looking away from the scene was excluded and I calculated the proportions of looking at the object, experimenter's hand, and elsewhere on the scene taken out of the total amount of active looking (up to six seconds). As predicted, non-parametric tests revealed that the reaching infants (*Mdn* = .54%) looked significantly more at the object, proportionately, than the non-reaching infants (*Mdn* = .40%; Mann-Whitney, $p = .04$; see Figure 13 in Appendix). Also as predicted, this same test revealed that the non-reaching infants (*Mdn* = .13%) looked significantly more at the experimenter's hand, proportionately, than the reaching infants (*Mdn* = .08%; Mann-Whitney, $p = .022$). There was no significant difference between groups in the amount of looking elsewhere (Mann-Whitney, $p = .36$).

In terms of within group differences, both groups looked significantly less at the experimenter's hand compared to the object or elsewhere, but there were no differences between looking at the object and elsewhere (see Table 3 in Appendix).

In addition to the durations, I was interested in the number of times each scene area of interest was looked at. A Group (2) x AOI (3) repeated measures ANOVA revealed a significant main effect of AOI only ($F(1, 33) = 131.36$, $p < .001$; see Figure 14 in Appendix), such that the experimenter's hand was looked at the least number of times (Non-reaching $M = .19$, $SD = .06$, Reaching $M = .15$, $SD = .07$) compared to the object (Non-reaching $M = .40$, $SD = .10$, Reaching $M = .45$, $SD = .08$) or elsewhere (Non-reaching $M = .42$, $SD = .10$, Reaching $M = .41$, $SD = .09$). However, there were no differences in the number of looks to either the object or elsewhere. This mirrors the pattern found for look durations with these same variables.

Visual Engagement with the Scene by Object. This analysis looking at visual attention out of the amount of active looking was also calculated for each object individually. The only between group difference was for the amount of looking at the object for the cup (see Figure 15 in Appendix), where the reaching group ($Mdn = .61\%$) looked more at the cup than the non-reaching group ($Mdn = .45\%$; Mann-Whitney, $p = .034$). Otherwise, there were no other between group differences.

In terms of within group differences (see Table 4 in Appendix), for the drumstick object, both groups had the same pattern of significance within group as for between. For the dumbbell and cup objects, the only diversion from this pattern was that for the reaching group, the infants looked significantly more at the object (Mdns = .63%, .45%, respectively) than they did elsewhere on the scene (Mdns = .27%, .32%, respectively; all ps < .01). The plain rod showed a less consistent pattern than the other objects—for the reaching group, the infants looked

significantly more at the plain rod (*Mdn* = .31%) than the experimenter's hand (*Mdn* = .14%; Wilcoxon, $p = .019$) and more elsewhere (*Mdn* = .55%) on the scene than the experimenter's hand (Wilcoxon, $p = .001$) but they also looked more elsewhere than the object (Wilcoxon, $p = .005$). In terms of the non-reaching group for the plain rod, the infants did look more elsewhere (*Mdn* = .60%) than the experimenter's hand (*Mdn* = .19%; Wilcoxon, $p = .001$), but the object versus experimenter's hand comparison for the plain rod was not significant (Wilcoxon, $p = .90$), and these infants looked significantly more elsewhere than they did at the plain rod (*Mdn* = .20%; Wilcoxon, $p = .001$).

Summary. Overall, these results show that when considering only the active looking, there was more looking to the object and less looking to the experimenter's hand in the reaching compared to the non-reaching group. There was no difference between groups in the amount of looking elsewhere. There were also virtually no between group differences for these variables among individual objects. Within both groups, there was proportionately less looking to the experimenter's hand than to either of the other scene areas of interest, and no difference in the amount of looking to the object and elsewhere.

Looking Distribution on the Objects

Durations of Looking to Objects Overall and Number of Looks between AOIs. The observed deviation in visual attention to the plain rod compared to the other objects prompted me to compare the total duration of looking at each object. A Group (2) x Object (4) repeated measures ANOVA revealed a main effect of object ($F(3, 35) = 46.80$, $p < .001$), such that the plain rod was looked at the least compared to the other objects (see Figure 16 in Appendix). However, there were no between group differences in the amount of looking to each object. I also compared the total number of looks for each object (see Figure 17 in Appendix). The term

'look' refers to the number of times the infants looked at an object within a trial; each time the infant looked at the object, then looked away from the object, then fixated back on the object again, was another look. A Group (2) x Object (4) repeated measures ANOVA revealed an effect of object ($F(3, 35) = 10.92$, $p < .001$), such that the plain rod was the object that had the greatest number of looks, and an effect of group ($F(1, 35) = 5.12$, $p = .03$), such that the non-reaching group had a greater number of looks to each object than the reaching group.

Specific Distribution of Looking Duration on Each Object. Next, I was interested in the allocation of visual attention on the objects themselves. Proportions of looking duration to each specific object area of interest were calculated out of the total amount of looking on the object for each trial. Non-parametric analyses did not show any between group differences in visual attention on the actual objects (see Figure 18 in Appendix), but there were several within group differences (see Table 5 in Appendix). The within group differences indicate that the infants' attention was drawn more to particular parts of the objects than others, and that this trend held for both groups.

Analyses on Number of Looks to Object AOIs. The last set of analyses that were performed was on the number looks to each specific object area of interest; again, this refers to the number of individual times each object area of interested was fixated.

Average Individual Look Durations. First, the average duration of each look to each object area was calculated by normalizing the duration to each area of interest by its respective number of looks to that area of interest. Non-parametric tests revealed that the only between group difference was a greater average duration of the looks to the cup body (Mann-Whitney, $p = .022$) in the reaching group ($Mdn = 2.33$ sec) than the non-reaching group ($Mdn = 1.5$ sec).

Otherwise, no other between group differences were found. Within group differences mirrored those of the proportions of looking duration to each area of interest (see Table 6 in Appendix).

Rate of Individual Look to Each Object Area of Interest. Next, I calculated the rate of looks per object area by normalizing the number of looks per area of interest by its respective duration of looking. Non-parametric tests revealed that the only group difference was fewer looks to the rod end of the drumstick object (Mann-Whitney, $p = 044$) in the reaching group ($Mdn = 2.00$) than in the non-reaching group ($Mdn = 2.52$). Within group differences are displayed in Table 7 (in Appendix).

Proportion of Looks to Each Object Area of Interest. Lastly, I calculated the overall proportion of looks to each object area of interest out of the total number of looks for each object. This non-parametric analysis also revealed group differences only for a greater proportion of looks to the sphere area of the drumstick object (Mann-Whitney, $p = .034$) in the reaching group ($Mdn = .68\%$) compared to the non-reaching group ($Mdn = .52\%$), and greater proportion of looks to the right and bottom ends of the plain rod object than the left or top ends (Mann-Whitney, $p = .01$) in the non-reaching group ($Mdn = .38\%$), compared to the reaching group ($Mdn = .19\%$). Within group differences are displayed in Table 8 (in Appendix).

Summary. Overall, these results show that the plain rod was the least looked at object of the four object types. There were no between group differences in how the infants scanned the individual objects, but there were differences for each object, such that the larger parts of the objects were looked at the most. The differences in number of looks to each of these object areas of interest showed similar patterns to the looking durations, such that there were no between group differences but similar within group differences.

CHAPTER IV: DISCUSSION

In this study I asked how visual attention is directed on a scene when infants have a goal to act on the scene compared to when they are looking with no intent to act. I made several predictions and several of them were confirmed. First, I found that when infants did not have an action goal, they spent more time looking away from the scene; in other words they were less engaged with the task. I also found that infants with a reaching goal looked more at the target object than those that did not have such a goal, while the group without the goal looked more at the experimenter's hand than the reaching-goal infants. The last major finding, which did not confirm my prediction, was that the infants without the action goal did not show a different pattern of scanning on the actual objects; instead, both groups showed the same focused pattern of looking, with visual attention being drawn to the larger parts of the objects the most.

Implications of Looking Away from the Scene

Implications for Infant Research. The current study has important implications for researchers who study infant visual attention both with looking paradigms alone and those who include other measures. My results showed that being able to interact with the scene increased visual attention, whereas the lack of interaction elicited more looking away from the scene. I would argue that including an active motor component into experimental procedures would be a valuable addition for two reasons. First, allowing infants to be manually engaged in tasks that require visual attention may address the problem of high attrition that comes with infant research. Infants tend to get fussy when they are bored, which can result in difficulty obtaining proper sample sizes and having to throw out data where infants are not cooperative. Giving infants the opportunity to interact with a task rather than just sitting back and watching a

presentation may help to increase and maintain attention to the task for longer, resulting in more usable data.

The second reason that adding a motor component to research on infant visual attention may be valuable relates to increased sustained attention. If activity increases sustained attention to looking paradigms, as evidenced by the disengagement when infants were not acting on the scene, it may add confidence to studies that visual presentations are being processed and encoded. The question of encoding was not directly addressed by my procedure and will be discussed more fully in a later section; but the point here is that sustained attention is essential to ensure learning in looking behavior paradigms, and motor interaction is one way to increase sustained attention. Recall also that reaching and non-reaching groups did not differ in latencies to their first fixations on the scene; however, as trials continued, the non-reaching group looked away from the scene more. This adds support to the notion that having an action goal in the reaching group helped to maintain attention to the scene, given that initial orienting to the scene did not differ, but visual engagement was lost as time progressed.

Link to Physiological Measures and Arousal. The finding that the non-reaching infants looked away from the scene more tells a lot about how infant attention is driven by action—when looking at a scene and processing it, visual attention to the scene matters. In my study, acting on the scene helped to increase and maintain sustained attention to the scene, whereas when not acting on the scene, attention was lost. Studies using physiological measures during sustained attention have found correlations between physiological responses and looking behavior that relate to my findings. They have found that when infants are sustaining attention to a particular stimulus, their heart rate decreases (Courage, Richards, & Reynolds, 2006), and the more complex the stimulus, the more attentive the infants are. These measures reflect

sustained attention better than just looking, and one could make the prediction that if a measure of heart rate were incorporated into my study, the reaching infants would show decreased heart rate, while the non-reaching infants would show a baseline level of heart rate. Similarly, one could argue that adding a component of action to the studies measuring looking and heart rate would increase the sustained attention to the task and may actually increase the effects of heart rate seen previously in these studies.

Additionally, Kidd et al. (2012) argued that an optimal amount of complexity of a scene elicits an optimal level of visual attention. While my study did not manipulate the complexity of the scene between groups, I did manipulate access to the objects presented in the scene, as well as the complexity of stimulus objects presented in both groups. It may be that offering the opportunity to act on a scene elicits a similar amount of visual attention as found in the Kidd et al. study. To expand on this, Gardner and Karmel (1984) found that an infant's state of arousal influences his preferences for differential stimulus complexity. In their study, infants in a state of low arousal preferred a more complex stimulus, and the reverse was also true. In the current study, perhaps the lack of action did not trigger enough arousal in the infants to maintain their attention toward the scene, whereas the opportunity to act on objects in the scene did.

Additionally, I did find that infants in both groups differentially looked at objects of different complexity. Objects varied in complexity based on the number of distinctive parts that comprised them. The plain rod was the least complex object, and as such drew the least visual attention overall. This supports the findings both by Kidd et al. (2012) and Cohen (1972) that the complexity of a stimulus affects the amount of visual attention directed toward it.

Implications of Visual Attention on the Scene

The finding that infants with an action goal look more at the target object than infants without the goal, and that infants without an action goal look more at the experimenter's hand than infants with an action goal suggests that the goal is altering the allocation of visual attention on a scene. For the infants in either group, the expectation is completely different—for the reaching infants, they build an expectation that the object presented to them is going to move forward and they will have the opportunity to reach for it. This expectation is driving their visual attention to the object of interest, on which they will act. In the non-reaching group, however, the infants build no such expectation because they never have the opportunity to act on the object. Instead, they build the expectation that they will not be able to act on the scene. Thus, their attention is not drawn as much to the object because it has less significance to them. Additionally, the lack of expectation of a goal may be driving the infants to look more at the experimenter's hand. In contrast, when the infants know what the goal is they are able to predict it, and this drives their attention.

Another explanation for more looking to the experimenter's hand in the non-reaching group is that they are expecting it to perform an action, as human hands often do. This would be interesting to test in a condition where the hand holding the object performs an action, but not an action directed toward the infant. For example, if the experimenter held the object out of reach for six seconds of looking but then moved the object to the side and put it down. In this case the hand is performing an action, but not in a way that the infant can act on it in turn. In this case, I might expect the infants in this group to increase visual attention to the hand even more because it is performing an action, but not directed at them. This would reflect the findings from studies, such as Falck-Ytter et al. (2006), where infant visual attention was focused on the hand of an

actor performing an action unrelated to the infant. One could even predict that if the hand suddenly started giving the object to the infant after several trials of moving it to the side, that attention would switch focus to the object as it would become more relevant to the infant.

Another study idea that would measure the visual attention process in real time is a within subject version of the current study. It would be interesting to present several trials with the non-reaching paradigm, then switch suddenly to the reaching procedure and measure the shift in visual attention. I would predict increased looking away from the scene during the first set of trials, then when the procedure switches I would expect a shift in visual attention more to the scene and more to the object, with less looking away.

Implications of Visual Attention on the Objects

It was surprising to me that I did not find a difference between the two groups in scanning patterns on the actual objects. Based on the findings from Corbetta et al. (2014), I expected that if the reaching group was planning to act on the object that they would focus their visual attention on the parts that they wanted to reach for, and that the non-reaching infants would show a more distributed pattern of looking because they were not planning an action on the objects; however, this was not the case. Both groups showed the same looking preferences for the same parts of the objects.

I believe that a bottom-up process is driving the infants' visual attention on the objects, such that the object properties are guiding attention to particular areas of the objects. For all objects except for the plain rod, there were one or more parts of the object that were larger and more distinct than others, and I saw that visual attention was focused on those areas. For the plain rod, I saw a more distributed pattern of looking because the object lacked the complexity and diversity of object parts that the other objects had. One major conclusion that can be made

from this finding overall is that the difference in visual attention is in attention and engagement with the scene, but not different when looking at the individual objects in the scene.

Limitations

One limitation to this study is that I was unable to accurately control for the six seconds of looking to the scene that I aimed to obtain. I had to estimate this myself by counting, and sometimes this resulted in over- or under-estimating this amount, which required me to control for this in the coding and analysis phase. If I had a software program that would stop the eye-tracker recording once six seconds of active looking was obtained, this problem could have been avoided and I could have made sure both groups were exposed to my stimuli for the same amounts of time.

An additional limitation to my study is the fact that with my procedure I was able to measure visual attention only, and unable to measure what was actually being processed or encoded by the infants in each group. A measure of encoding would have provided information about how the amount of visual attention to the scene is influencing what is actually being learned and remembered. Does continuity in looking compared to looking with gaps allow for better encoding of the objects? I saw that the infants looked at the objects in the same way, but I do not know if they were still getting the same information from just looking at them versus looking and then acting. Research has shown that infants who exhibit shorter looks actually process information more efficiently than infants who exhibit longer looks to stimuli (Jankowski & Rose, 1997). So, it is possible that the non-reaching infants may have processed the objects just as well as the reaching infants, but lost interest in looking upon realizing they would not get to interact with the objects, thus visual attention was no longer required. However, this is something that I could not measure with my paradigm.

A third limitation to my study, which could possibly be considered a confound, is that not only did the reaching infants get to reach for the objects, but they were also given a few seconds to play with each object before moving on to the next trial. That introduces an additional component that could be driving my results, getting to interact with the objects for a prolonged amount of time in addition to just acting on them. This sustained interaction with the objects adds an expectation and a goal, which may have helped to maintain the infants' attention to the scene. To control for this, I could have allowed the infants to play with an object in between trials that they did not reach for. Thus, this would have eliminated the confound of engaging with objects but maintain the lack of individual action on the scene, because the infants would not have reached for them themselves. If the engagement with the objects alone is increasing visual attention then my effects would disappear; however, I suspect that this would not be the case. I would argue that having a goal-directed action is truly driving the visual attention to the scene, and thus, being handed a different object after observing the scene would not be enough to drive attention. In fact, it may actually distract the infants to the point where they would be less attentive to the object presentations; if they know they will be handed a different object if they wait long enough, there is no need to look at the scene for which they cannot interact.

Lastly, this study only tested 7-month-olds, but it would be valuable to test infants younger and older than this with this procedure, to compare whether action maintains the same influence on visual attention across infancy or if this is something that develops. It is also possible that action becomes less important for attention over time. But I would need to test more ages to observe these effects.

Conclusions

The main conclusion from this study is that action is important in guiding and maintaining visual attention to a scene in 7-month-old infants. This has important implications for infant researchers but also for parents, in terms of encouraging action in play rather than just watching media on screens. My recommendation is that researchers incorporate motor action tasks when measuring attention, in order have more confidence that the infants are visually engaged in their tasks and actually processing their stimuli. Additionally, this may help researchers to prolong engagement with their tasks and keep the infants from losing interest. I would also recommend that parents incorporate activity into their routines rather than letting infants passively sit in front of screens. Again, I cannot say from my study whether watching screens without acting inhibits learning, but I can speculate that if action increases attention, then it also will increase cognitive activity while engaged with the task. The findings from the current study open the door to investigating how important action is for other domains in cognition, in addition to attention, such as encoding, processing, and learning.

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APPENDIX

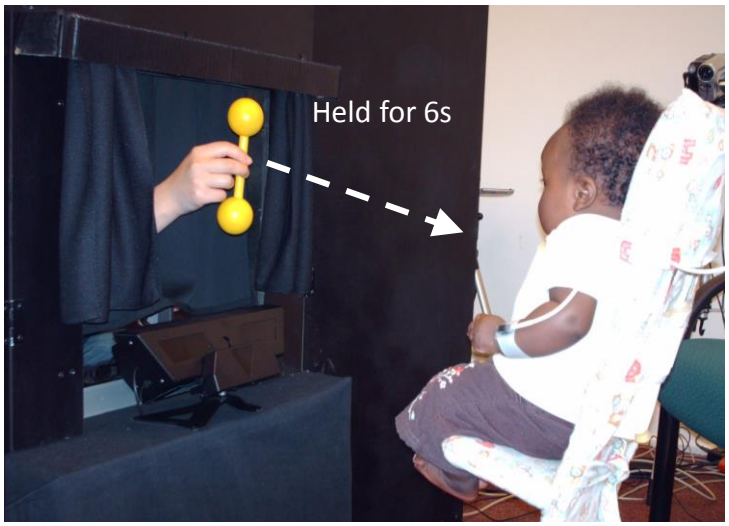


Figure 1. Experimental Set-up



Figure 2. Stimulus objects

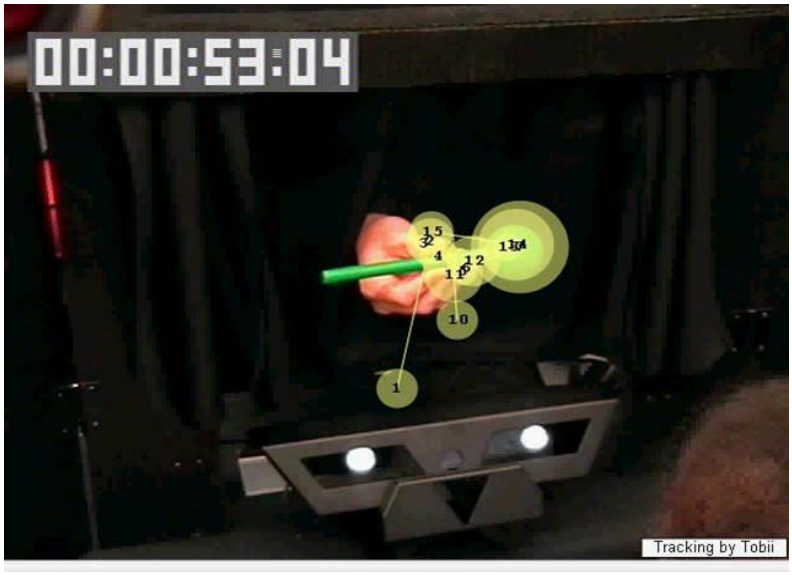


Figure 3. Example of fixation points on the scene

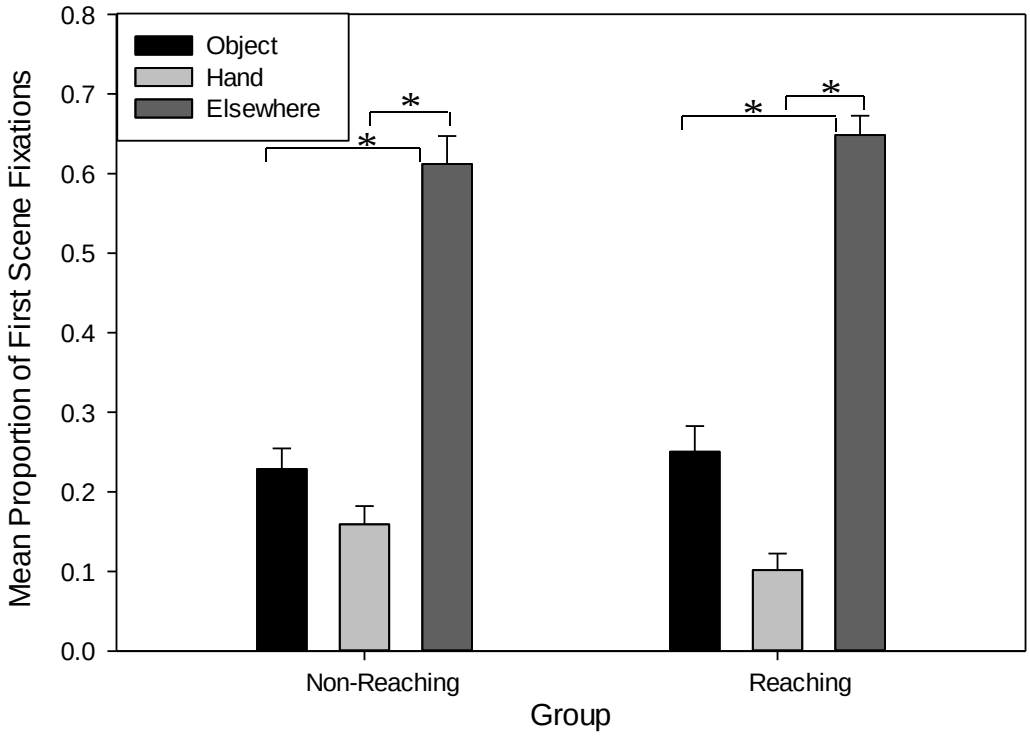


Figure 4. Proportion of First Scene Fixations by AOI and by Group

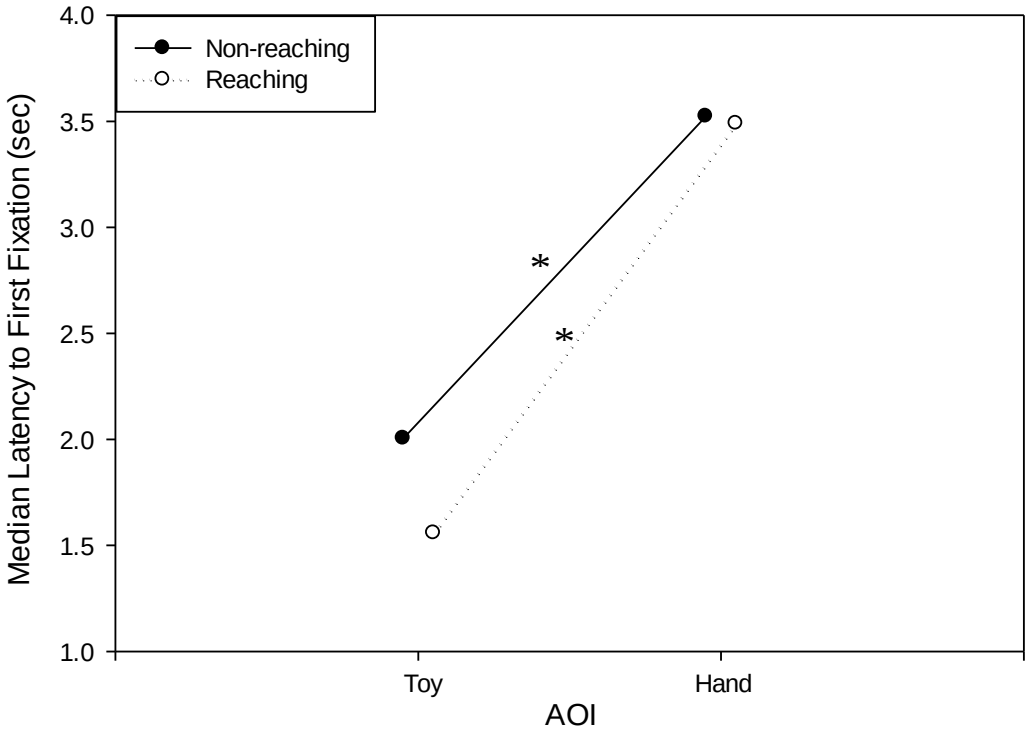


Figure 5. Latency to First Fixation on Object and Experimenter's Hand by Group

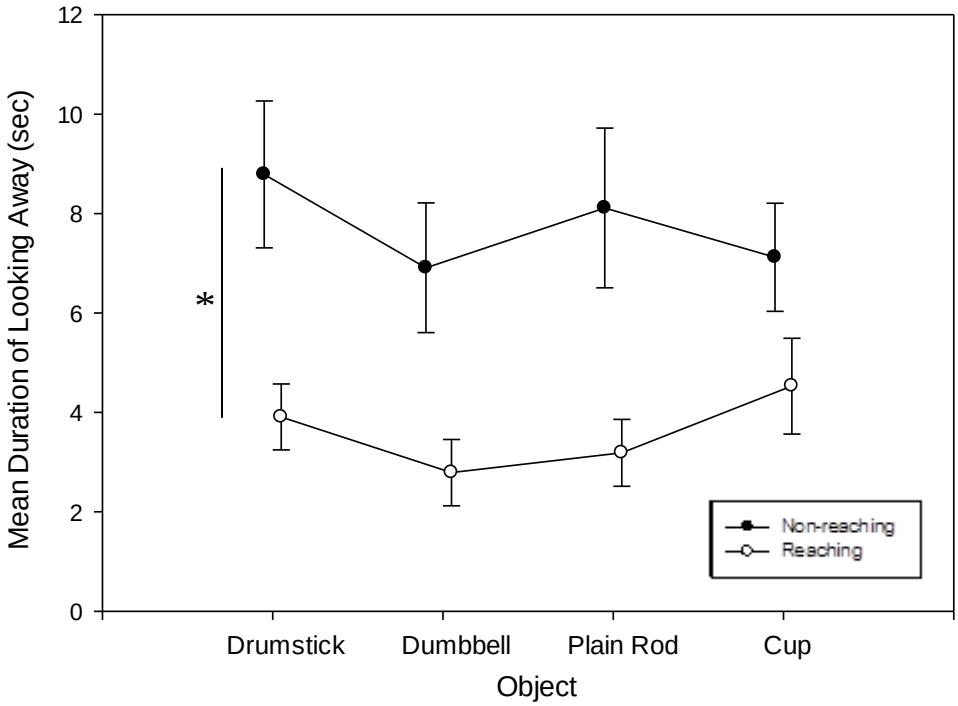


Figure 6. Accumulated Duration of Looking Away from the Scene by Object and by Group

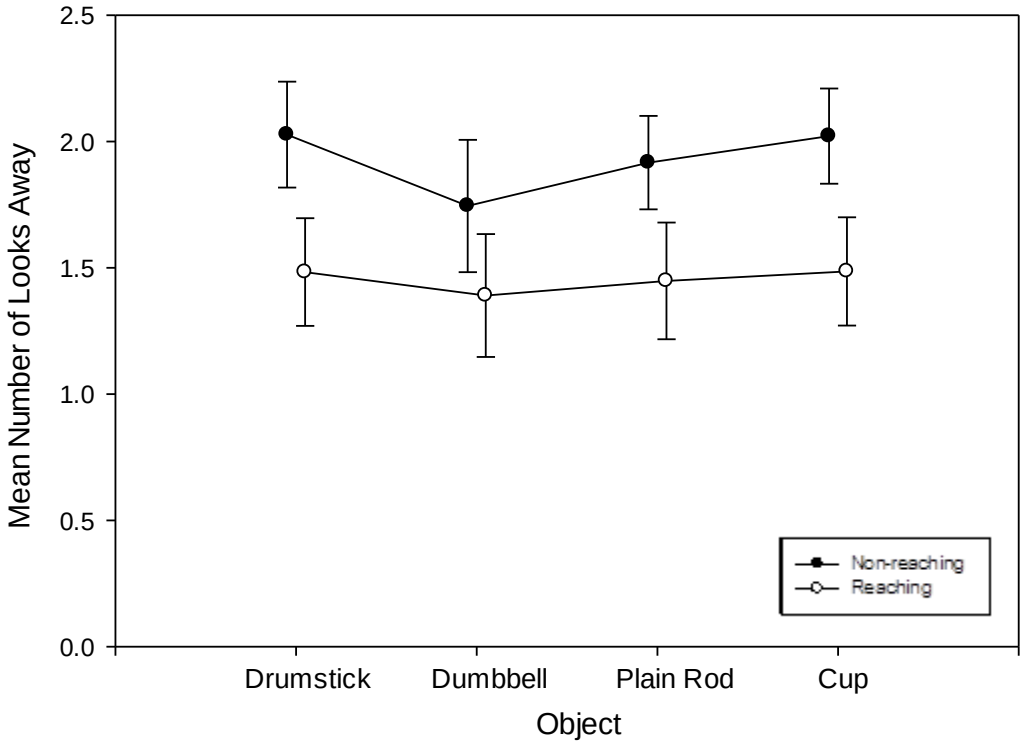


Figure 7. Number of Times Infants Looked Away from the Scene by Object and by Group

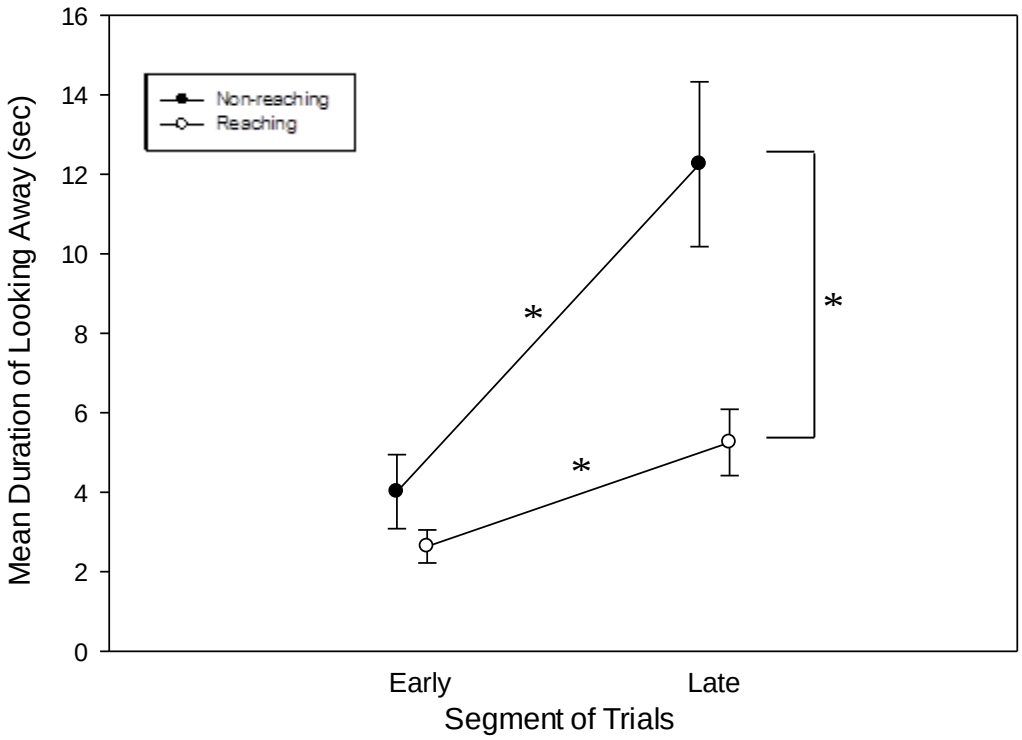


Figure 8. Early and Late Trial Analysis for Look Away Duration by Group

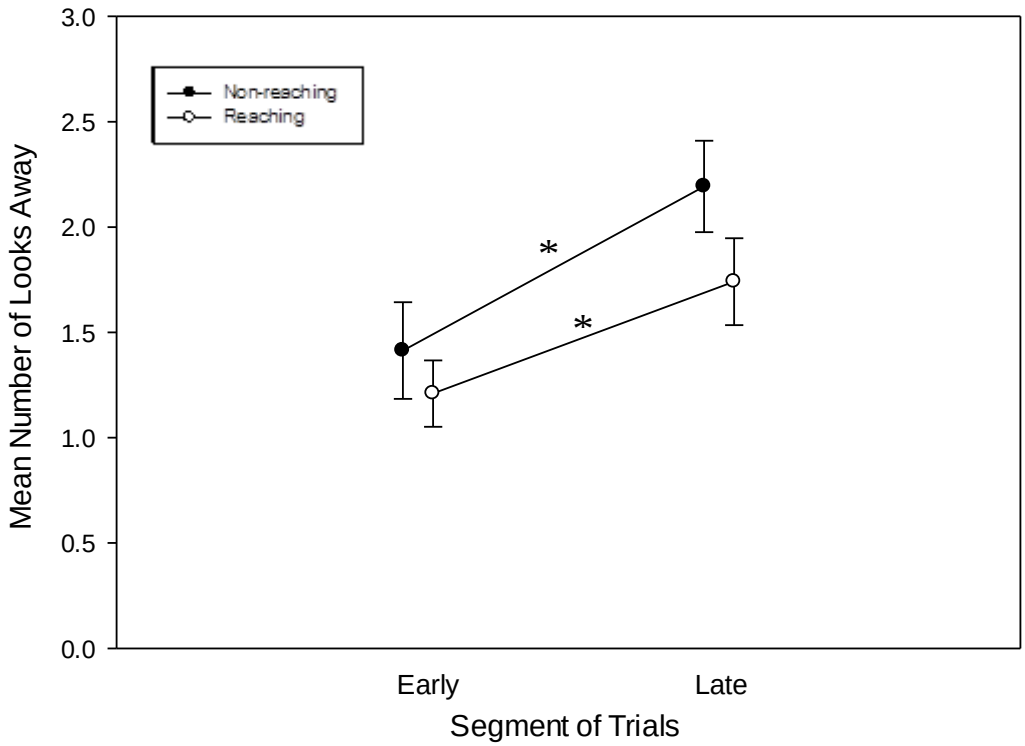


Figure 9. Early and Late Trial Comparison for Number of Times Infants Looked Away by Group

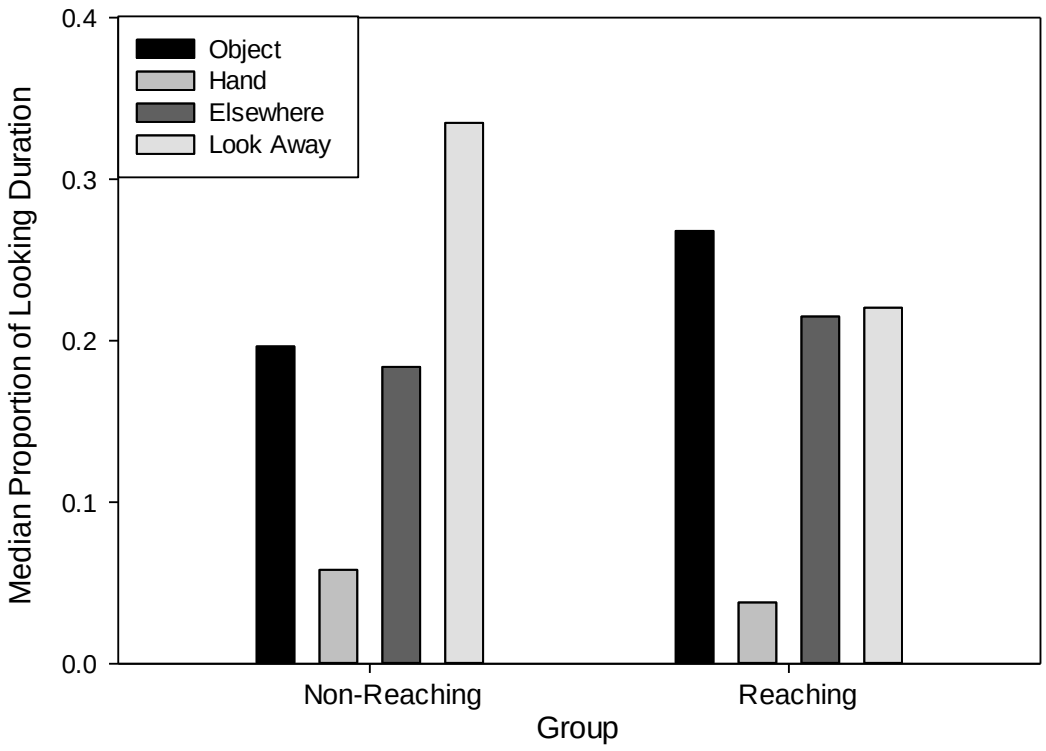


Figure 10. Proportions of Looking Duration to AOIs on the Scene out of Trial Duration

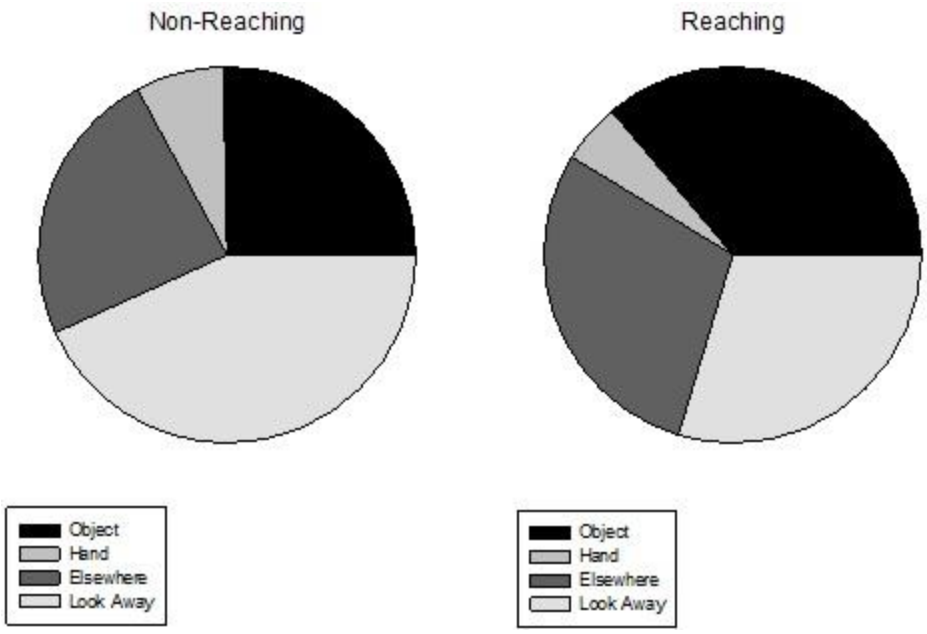


Figure 11. Pie Chart Representation of Proportions of Looking Duration to AOIs on the Scene out of Trial Duration by Group

Table 1.

P-Values for Within Group Comparisons of Looking Duration to AOIs on the Scene out of Trial Duration

AOI Comparison	Non-reaching	Reaching
Object vs. Hand	0.000	0.000
Object vs. Elsewhere	0.983	0.078
Object vs. Look Away	0.022	0.879
Hand vs. Elsewhere	0.000	0.000
Hand vs. Look Away	0.000	0.001
Elsewhere vs. Look Away	0.020	0.446

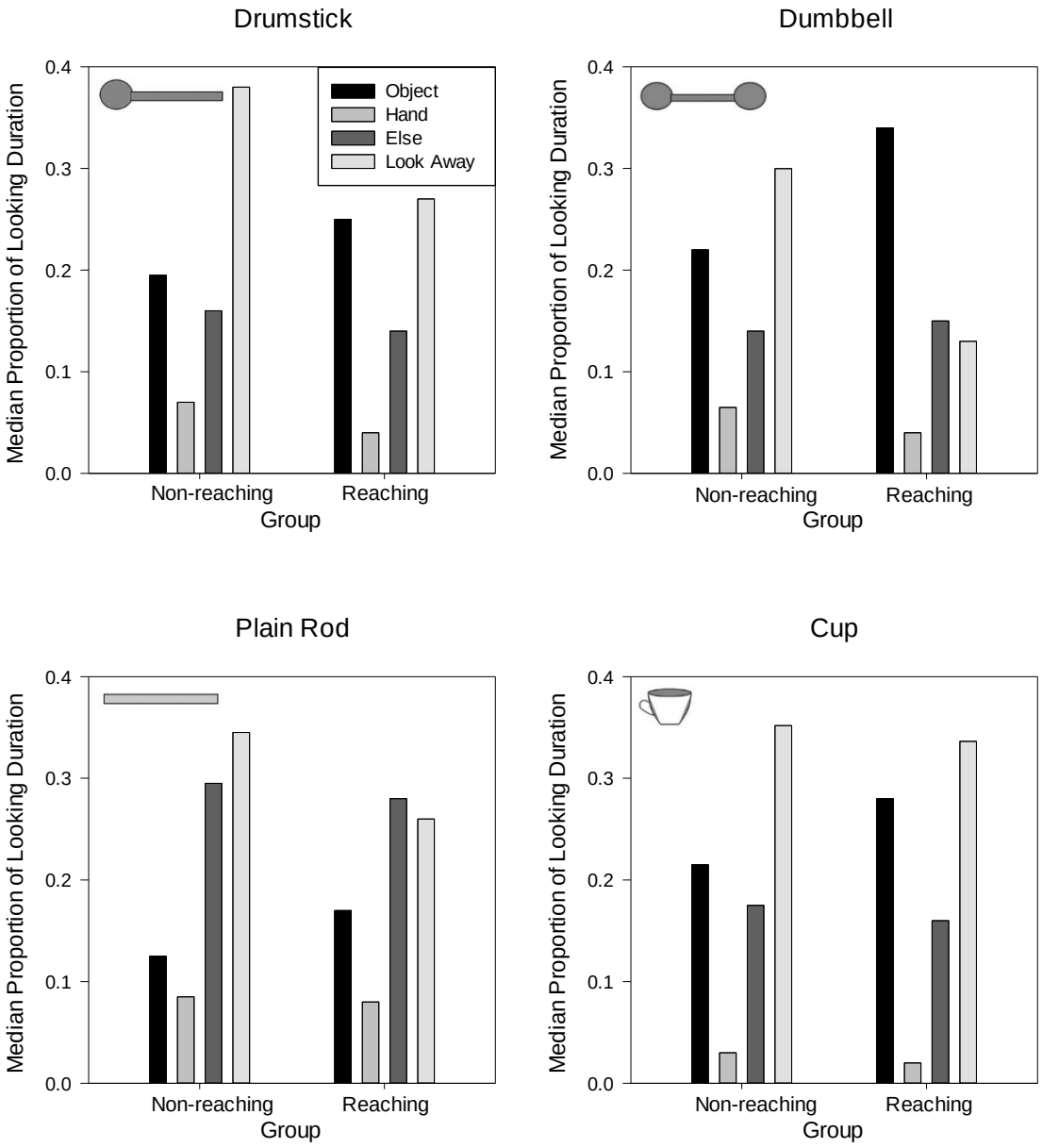


Figure 12. Proportions of Looking Duration to AOIs on the Scene out of Trial Duration, by Object

Table 2.

P-Values for Within Group Comparisons of Looking Duration to AOIs on the Scene out of Trial Duration, by Object

Drumstick		
AOI Comparison	Non-reaching	Reaching
Object vs. Hand	0.000	0.000
Object vs. Elsewhere	0.492	0.112
Object vs. Look Away	0.05	0.930
Hand vs. Elsewhere	0.001	0.000
Hand vs. Look Away	0.000	0.001
Elsewhere vs. Look Away	0.015	0.224

Dumbbell		
AOI Comparison	Non-reaching	Reaching
Object vs. Hand	0.000	0.000
Object vs. Elsewhere	0.24	0.002
Object vs. Look Away	0.486	0.058
Hand vs. Elsewhere	0.000	0.000
Hand vs. Look Away	0.000	0.006
Elsewhere vs. Look Away	0.052	0.420

Plain Rod		
AOI Comparison	Non-reaching	Reaching
Object vs. Hand	0.471	0.026
Object vs. Elsewhere	0.001	0.004
Object vs. Look Away	0.001	0.177
Hand vs. Elsewhere	0.001	0.001
Hand vs. Look Away	0.000	0.029
Elsewhere vs. Look Away	0.632	0.523

Cup		
AOI Comparison	Non-reaching	Reaching
Object vs. Hand	0.000	0.000
Object vs. Elsewhere	0.372	0.026
Object vs. Look Away	0.016	0.948
Hand vs. Elsewhere	0.000	0.000
Hand vs. Look Away	0.000	0.000
Elsewhere vs. Look Away	0.004	0.112

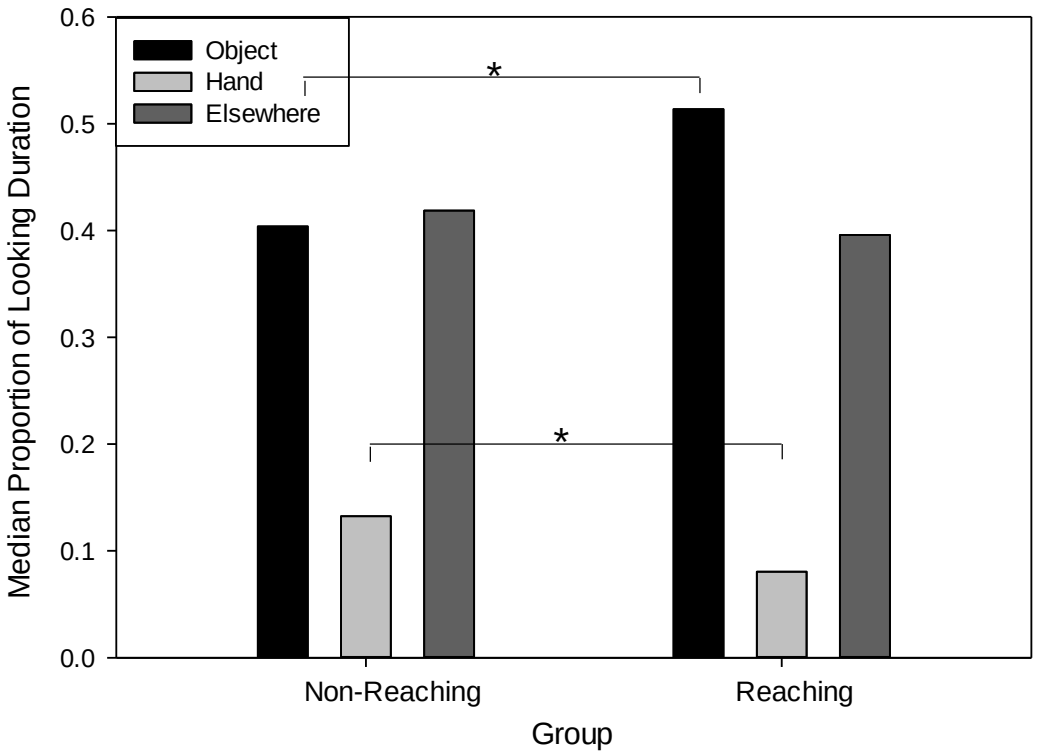


Figure 13. Median Proportions of Looking Duration to AOIs on the Scene During Active Looking by Group

Table 3.

P-Values for Within Group Comparisons of Looking Duration to AOIs on the Scene During Active Looking

AOI Comparison	Non-reaching	Reaching
Object vs. Hand	0.000	0.000
Object vs. Elsewhere	0.811	0.064
Hand vs. Elsewhere	0.000	0.000

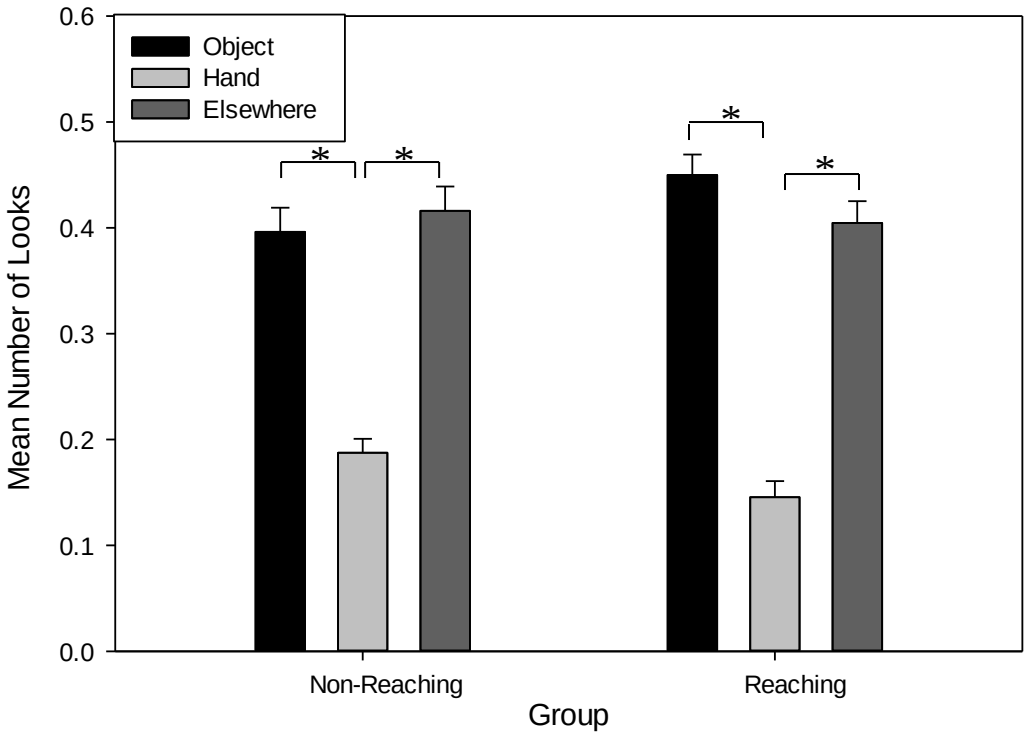


Figure 14. Number of Looks to AOIs on the Scene During Active Looking by Group

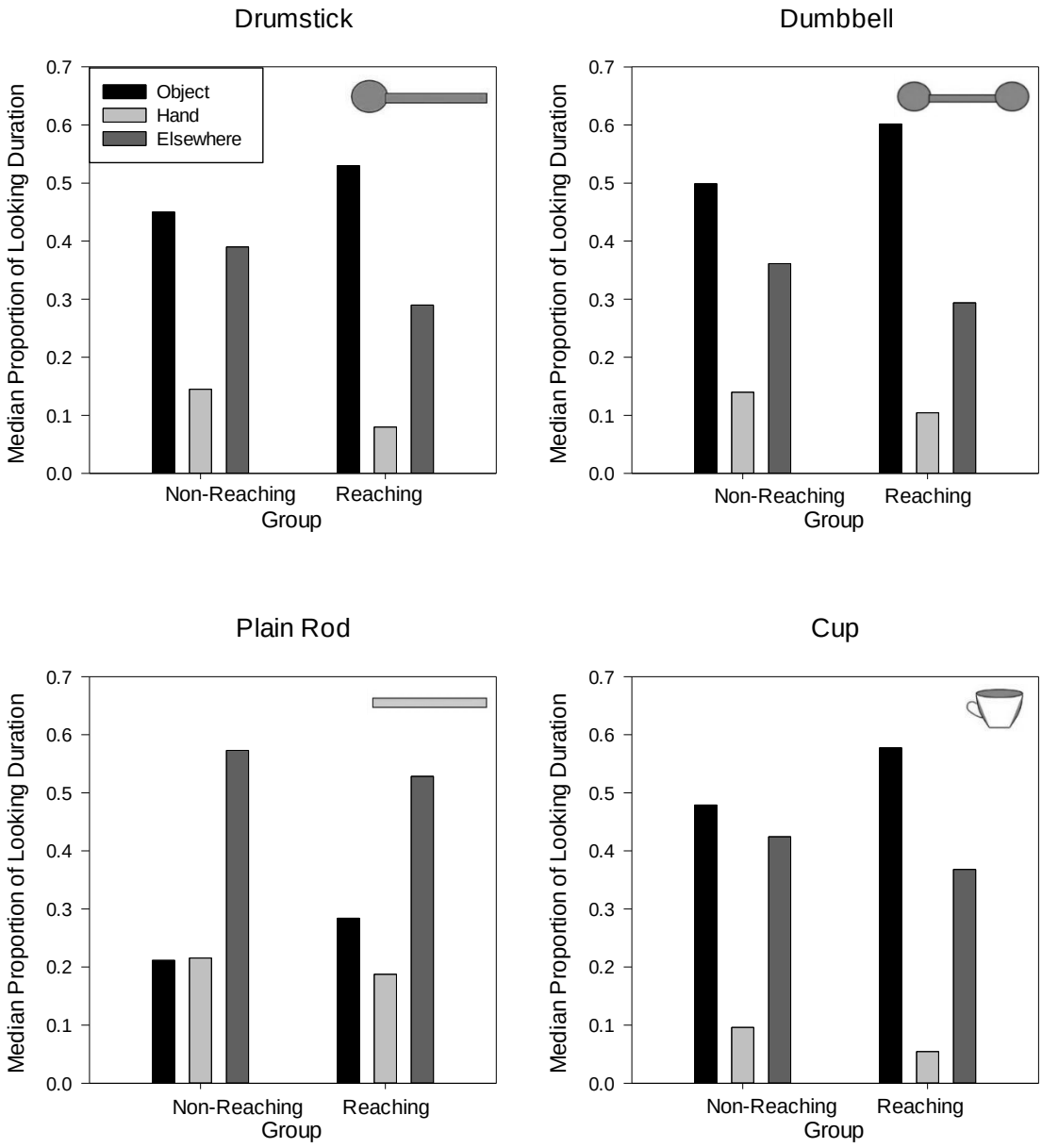


Figure 15. Median Proportions of Looking Duration to AOIs on the Scene During Active Looking, by Object and by Group

Table 4.

P-Values for Within Group Comparisons of Looking Duration to AOIs on the Scene During Active Looking, by Object

Drumstick		
AOI Comparison	Non-reaching	Reaching
Object vs. Hand	0.000	0.000
Object vs. Elsewhere	1.000	0.122
Hand vs. Elsewhere	0.001	0.000
Dumbbell		
AOI Comparison	Non-reaching	Reaching
Object vs. Hand	0.000	0.000
Object vs. Elsewhere	0.276	0.001
Hand vs. Elsewhere	0.000	0.000
Plain Rod		
AOI Comparison	Non-reaching	Reaching
Object vs. Hand	0.896	0.019
Object vs. Elsewhere	0.001	0.005
Hand vs. Elsewhere	0.001	0.001
Cup		
AOI Comparison	Non-reaching	Reaching
Object vs. Hand	0.000	0.000
Object vs. Elsewhere	0.636	0.010
Hand vs. Elsewhere	0.000	0.000

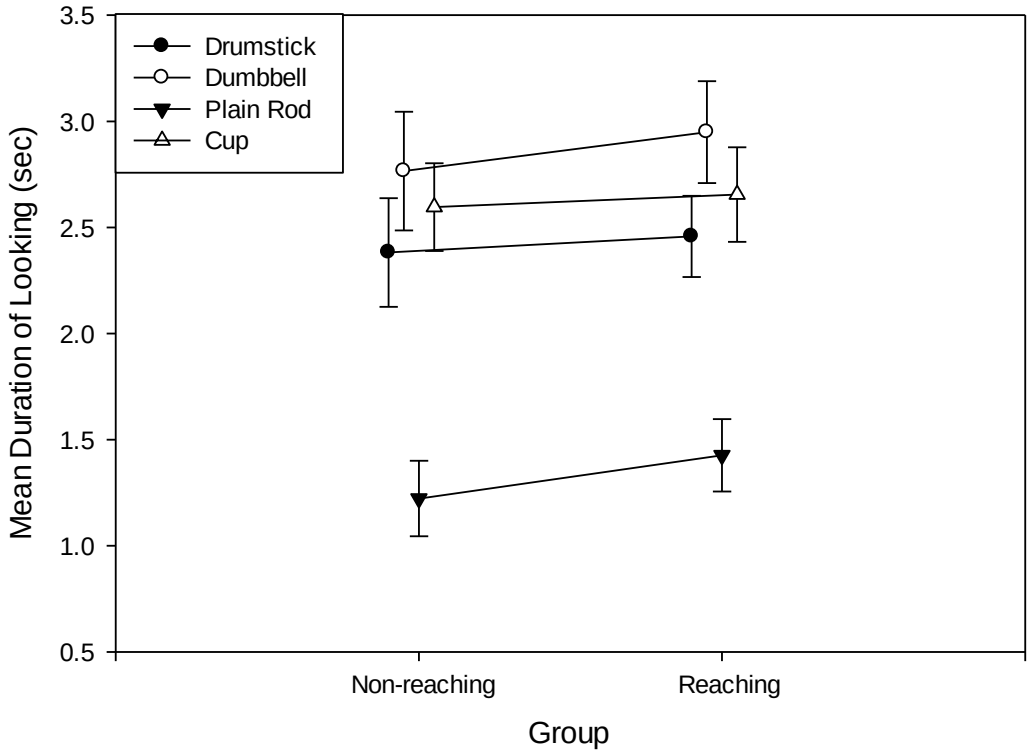


Figure 16. Overall Looking Duration to Each Object by Group

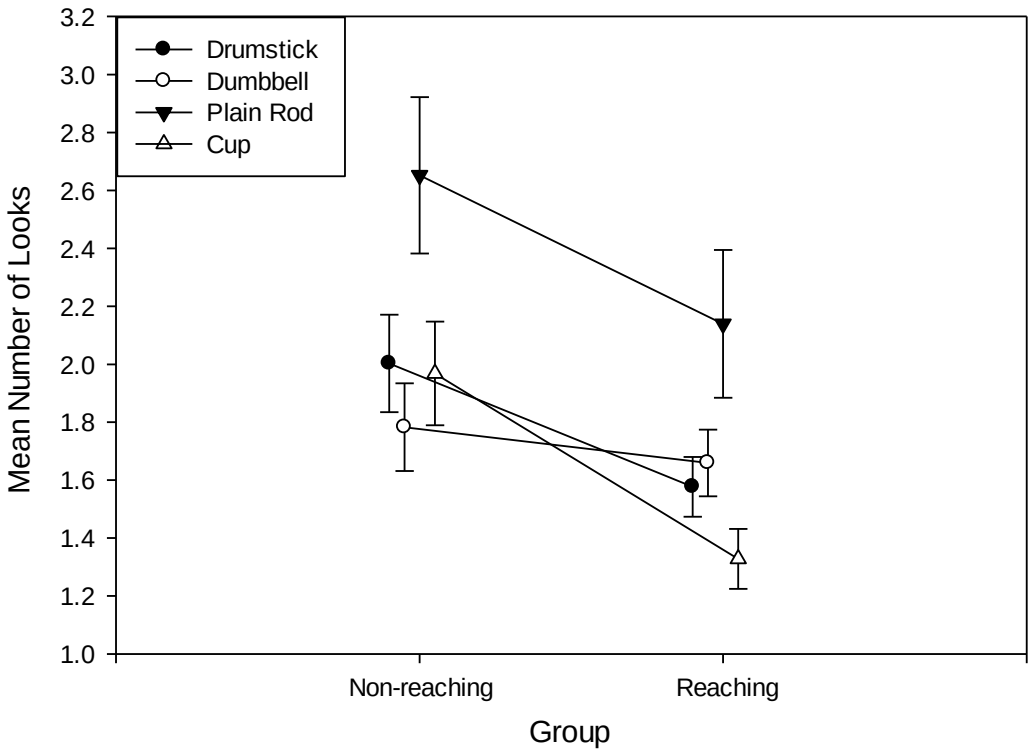


Figure 17. Overall Number of Looks to Each Object by Group

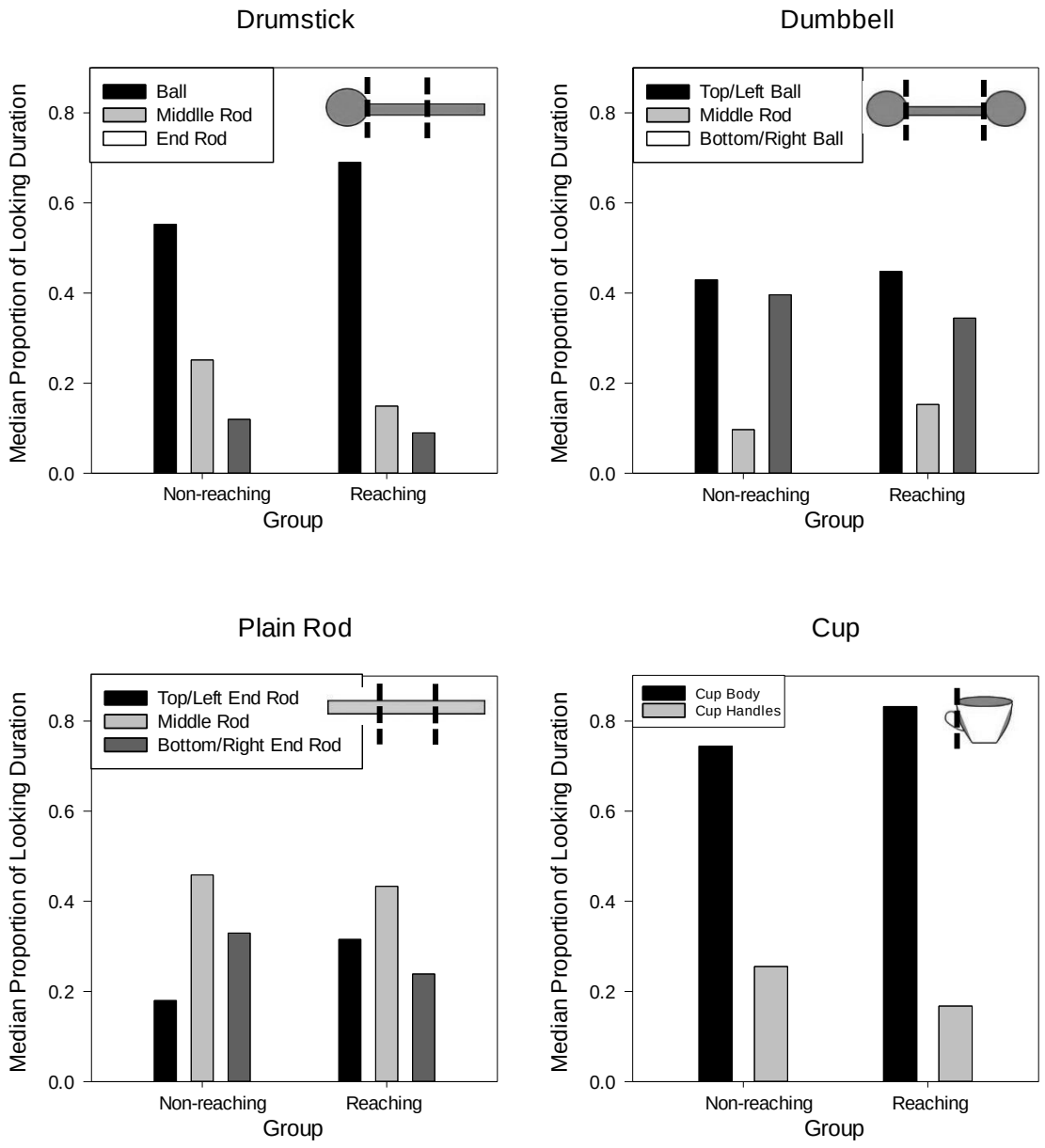


Figure 18. Distribution of Looking on Each Object

Table 5.

P-Values for Within Group Comparisons for Looking Distribution on Each Object

Drumstick		
AOI Comparison	Non-reaching	Reaching
Ball vs. Middle Rod	0.003	0.001
Ball vs. End Rod	0.000	0.000
Middle Rod vs. End Rod	0.102	0.231
Dumbbell		
AOI Comparison	Non-reaching	Reaching
Left/Top Ball vs. Middle Ball	0.001	0.000
Left/End Ball vs. Right/Bottom Ball	0.500	0.112
Middle Rod vs. Right/Bottom Ball	0.004	0.008
Plain Rod		
AOI Comparison	Non-reaching	Reaching
Left/Top End Rod vs. Middle Rod	0.044	0.287
Left/Top End Rod vs. Right/Bottom End Rod	0.408	0.136
Middle Rod vs. Right/Bottom End Rod	0.287	0.006
Cup		
AOI Comparison	Non-reaching	Reaching
Cup Body vs. Cup Handles	0.000	0.000
Top Body vs. Middle Body	0.035	0.744
Top Body vs. Bottom Body	0.001	0.008
Middle Body vs. Bottom Body	0.002	0.001
Left Handle vs. Right Handle	0.140	0.959

Table 6.

P-Values for Within Group Comparisons for Average Individual Look Duration for Each Object

Drumstick		
AOI Comparison	Non-reaching	Reaching
Ball vs. Middle Rod	0.003	0.000
Ball vs. End Rod	0.001	0.004
Middle Rod vs. End Rod	0.777	0.215
Dumbbell		
AOI Comparison	Non-reaching	Reaching
Left/Top Ball vs. Middle Ball	0.149	0.002
Left/End Ball vs. Right/Bottom Ball	0.043	0.170
Middle Rod vs. Right/Bottom Ball	0.010	0.035
Plain Rod		
AOI Comparison	Non-reaching	Reaching
Left/Top End Rod vs. Middle Rod	0.246	0.925
Left/Top End Rod vs. Right/Bottom End Rod	0.407	0.163
Middle Rod vs. Right/Bottom End Rod	0.744	0.224
Cup		
AOI Comparison	Non-reaching	Reaching
Cup Body vs. Cup Handles	0.018	0.004
Top Body vs. Middle Body	0.267	0.170
Top Body vs. Bottom Body	0.004	0.112
Middle Body vs. Bottom Body	0.004	0.007
Left Handle vs. Right Handle	0.061	1.000

Table 7.

P-Values for Within Group Comparisons for Rate of Looks for Each Object

Drumstick		
AOI Comparison	Non-reaching	Reaching
Ball vs. Middle Rod	0.007	0.004
Ball vs. End Rod	0.012	0.306
Middle Rod vs. End Rod	0.170	0.012
Dumbbell		
AOI Comparison	Non-reaching	Reaching
Left/Top Ball vs. Middle Ball	0.523	0.002
Left/End Ball vs. Right/Bottom Ball	0.199	0.231
Middle Rod vs. Right/Bottom Ball	0.053	0.071
Plain Rod		
AOI Comparison	Non-reaching	Reaching
Left/Top End Rod vs. Middle Rod	0.076	0.619
Left/Top End Rod vs. Right/Bottom End Rod	0.163	0.653
Middle Rod vs. Right/Bottom End Rod	0.557	0.717
Cup		
AOI Comparison	Non-reaching	Reaching
Cup Body vs. Cup Handles	0.002	0.007
Top Body vs. Middle Body	0.679	0.679
Top Body vs. Bottom Body	0.811	0.983
Middle Body vs. Bottom Body	0.528	0.420
Left Handle vs. Right Handle	0.826	0.352

Table 8.

P-Values for Within Group Comparisons for Proportion of Looks for Each Object

Drumstick		
AOI Comparison	Non-reaching	Reaching
Ball vs. Middle Rod	0.011	0.001
Ball vs. End Rod	0.000	0.000
Middle Rod vs. End Rod	0.084	0.026
Dumbbell		
AOI Comparison	Non-reaching	Reaching
Left/Top Ball vs. Middle Ball	0.001	0.001
Left/End Ball vs. Right/Bottom Ball	0.102	0.184
Middle Rod vs. Right/Bottom Ball	0.009	0.016
Plain Rod		
AOI Comparison	Non-reaching	Reaching
Left/Top End Rod vs. Middle Rod	0.076	0.795
Left/Top End Rod vs. Right/Bottom End Rod	0.438	0.023
Middle Rod vs. Right/Bottom End Rod	0.246	0.010
Cup		
AOI Comparison	Non-reaching	Reaching
Cup Body vs. Cup Handles	0.000	0.003
Top Body vs. Middle Body	0.043	0.931
Top Body vs. Bottom Body	0.001	0.061
Middle Body vs. Bottom Body	0.002	0.010
Left Handle vs. Right Handle	0.256	0.959

VITA

Rebecca Faith Wiener was born in Abington, Pennsylvania to Ellen and Stephen Wiener. She has two younger brothers, Joel and Jeffrey. She attended Thomas Fitzwater Elementary School and continued to Sandy Run Middle School, then Upper Dublin High School in Fort Washington, Pennsylvania. She then pursued a psychology major at Clemson University in South Carolina, where she earned a Bachelor of Arts degree in the subject in May 2012. Rebecca accepted a graduate position at the University of Tennessee, Knoxville, where she is currently doing research towards her masters and Ph.D. degrees in Experimental Psychology—Developmental, and where she also teaches an introductory psychology course.