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Assessing the Role of Biased Competition in 5- and 11-month-old Infants

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To the Graduate Council:

I am submitting herewith a thesis written by Amanda Marie Ainsley entitled "Assessing the Role of Biased Competition in 5- and 11-month-old Infants." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Arts, with a major in Psychology.

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Assessing the Role of Biased Competition in 5- and 11-month-old Infants

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ABSTRACT

In order to make sense of the world around us, our brains must learn to quickly and accurately integrate information from one eye movement to the next. Our ability to integrate this information develops rapidly over the first year of life. Previous research has indicated that when both adults and infants are storing information in their visual memory system, this information guides future eye movements and leads to the formation of a preference to look towards or away from novel items. Additionally, adult vision research has indicated that very basic reflexive eye movements are influenced by visual information being retained in visual short-term memory. Given this research, several questions remained. The present study was designed to test if the eye movements of infants at 5- and 11-months change as a function of information being retained in their visual short-term memory systems, how this varies between age groups, and how the length of time an infant spends viewing an item alters the formation of looking preferences. The results indicated that infants did not exhibit faster reaction times to, or develop a preference for novel or familiar items.

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CHAPTER I: INTRODUCTION

The average human makes approximately 3-4 eye movements each waking second, and an approximate 10,000 eye movements every hour (Tovée, 2008). As the visual system is rapidly developing in infancy, these eye movements are becoming increasingly accurate, but the visual system must still learn to integrate information from one eye movement to the next. (Aslin & Salapatek, 1975). The primary function of our visual short-term memory, or VSTM, is the short-term storage and maintenance of this visual input (Baddeley & Hitch, 1974; Vogel et al., 2006), and it is essential to our ability to integrate visual information from the world around us across eye movements (Henderson & Hollingworth, 2003; Hollingworth & Henderson, 2002).

The information that is being held in VSTM influences subsequent eye movements (Hollingworth et al., 2013). For instance, imagine a trip to the grocery store. You enter the store, grocery list in hand and begin searching for the items you'll need. You are searching for a particular canned vegetable, and as you're walking down the canned good aisle and scanning the shelves, your visual system is being inundated with information. Items that share similar features (shape, size, color, etc.) of the one you are looking for vie for your attention. While visualizing the item you're looking for, you're holding those features in your VSTM system, and your visual system begins to bias your eye movements towards features that match what you're holding in your VSTM, until finally you're able to recognize what you'd been looking for and make your selection. While the contents of VSTM do bias looking behavior in adults (Hollingworth et al., 2013), it remains to be seen how the infant VSTM system operates under similar conditions. As we move our eyes from one place to the next throughout our day-to-day lives, we operate on a constant feedback loop between visual perception and looking behaviors. As our brains develop and we gain more experience moving our eyes from point to point to obtain information, this process becomes more reliable and fewer corrective eye movements are needed (Simmering, 2012). However, less is known about how this system operates to influence looking in the first postnatal year. How do infants respond to new visual input while holding existing information in the VSTM?

Although many of the eye movements we make as adults are not goal-oriented and rely only on basic oculomotor functions – say when we see a flash in our periphery and immediately orient towards it – the role of VSTM is still evident, and these basic functions are still subject to competition stemming from the contents of VSTM (Beck et al., 2012; Hollingworth et al., 2013). What remains to be seen is how infants respond when presented with similar situations. Do the images maintained in their VSTM influence their looking behaviors as well? And if so, in what ways? The current project was designed with these questions in mind, and the historical and theoretical contexts of each will be discussed in the coming pages.

Understanding how the contents of VSTM influence these moment-to-moment eye movements is essential to understanding the neural mechanisms that underlie these behaviors. Examining how these eye movements change during development also helps shed light on the development of these systems. Additionally, understanding what these behaviors look like in full-term, typically developing infants will ultimately help identify outliers and potentially spot those who may have higher-risk developmental trajectories. For instance, while the relationship between neuropsychopathology and memory is not entirely clear, abnormalities in VSTM have been implicated in childhood ADHD (Castellanosa et al., 2006; Willcutt et al., 2005), childhood schizophrenia (Cullen et al., 2010; Sørensen et al., 2006), high-functioning autism and Tourette Syndrome (Verté et al., 2006). Research has consistently demonstrated that even brief visual presentation of objects can influence and guide future looking behavior across stages of development, (Downing & Dodds, 2004; Mitsven et al., 2018) including how long someone looks at a given object (fixation duration), or how quickly they move their eyes when an object appears (reaction time). As we move our eyes, our visual system works like a camera, producing static images each time they land, and we rely heavily on our VSTM to convert these static images into one coherent image (Bays & Husain, 2012; Buss et al., 2018; Luck & Vogel, 1997; Oakes et al., 2013).

CHAPTER II: LITERATURE REVIEW

The field of infant visual development has focused its efforts on understanding how infants gain the skills to navigate the world around them, and how complex visual input makes its way throughout the memory system (Colombo, 2001; Johnson & De Haan, 2015; Nelson, 2008). Here I will discuss the support of the biased competition model, which suggests that currently held information from VSTM guides future visual behaviors, as well as the paradigm shifts of measuring VSTM.

VSTM and Eye Movements: Theoretical Background

In 1995, Desimone and Duncan developed a series of studies that supported the notion that when visual information is presented (even for very brief periods), this information is stored and influences future looking behavior towards information that is needed for the current behavior. In their review, they discuss the biased competition model as it pertains to monkeys performing a visual search task. In this task, monkeys were briefly presented a complex object (300ms), followed by a delay (3000ms) and a forced choice test display (600ms) between the familiar and an added novel items. They found that monkeys made eye movements to the target that matched the previously presented items. This led to the understanding that brief visual exposures bias subsequent looking behaviors at test (Desimone & Duncan, 1995).

Desimone and Duncan posited that visual information is constantly competing for our attention, and that the process of *attending to* something creates a mental representation or memory. Further, they argue that when new visual input is pitted against previously attended items, the competition between these simultaneous streams of input is biased towards relevant information; if more information is needed complete a representation of a particular item, looking will be biased towards that item and conversely, if an object has become adequately familiarized and a complete mental representation is formed, no more information is needed and we begin seeking information about novel items. They argue that due to limited processing capacity within visual cortex, if an individual still has an active memory trace of a previously fixated item, the familiarity of that object will bias the competition towards that item when subjects are forced to compare that item to a new item at test. They stipulate that the maintenance of an item in VSTM increases the likelihood that attention will be directed toward that item or an item that has similar features as the familiar item. This is to say that attending to and holding an item in VSTM leads to a competitive advantage for that item compared to others, as activation of that particular mental representation is already at a heightened state (Desimone & Duncan, 1995). This shed light on how VSTM influences the execution of future eye movements in both adults and infants. While less is known about how biased competition might interplay with orienting and preference formation in infancy, research demonstrating the linkage between these processes in adulthood has demonstrated that when adults hold information in VSTM, this input guides subsequent looks towards familiar items, even after very brief exposure periods (Beck et al., 2012; Hollingworth et al., 2013; Hollingworth & Luck, 2009; Woodman & Luck, 2007).

To further illustrate this, Hollingworth and colleagues found that when adults are retaining information in VSTM, this information has the capacity to influence very basic oculomotor functions like orienting (2013). In this task, subjects were briefly presented a single colored square (300ms) and were told to remember it. Following a 700ms blank retention interval, a colored circle was presented to the right or left of central fixation, that either matched the color subjects were holding in memory (familiar), or did not (novel). Regardless of match condition, subjects were instructed to move their eyes towards the target items as quickly as possible. Results demonstrated that subjects oriented significantly faster to the familiar colored circle compared to the novel colored circle. While this does not speak to the formation of a preference, it demonstrates the ability of VSTM to guide rapid-eye movement and hints at a connection between higher-level cognitive processes and basic reflexive orienting behaviors (Hollingworth et al., 2013). Although reflexive eye movements are present from birth (Colombo, 2001; Dannemiller, 1998; Johnson & De Haan, 2015; Ross-Sheehy et al., 2015), it is currently unclear if higher-level cognitive processes such as VSTM influence infant eye movements in a similar manner – particularly given the limited capacity of VSTM in infants. Following is a brief review of VSTM research in infancy, including techniques and major findings.

Assessing VSTM in Infancy

Studying individual and group differences in VSTM development early in life has helped to shed light on the development of infant memory and brain development (Fitch et al., 2016; Perone et al., 2011; Postle, 2015; Xu, 2009). Various paradigms have been developed to assess VSTM, many of which stem from the wealth of research surrounding habituation and familiarization, and the development of looking preferences that coincide these mechanisms. Here I will discuss the common methods of measuring VSTM as well as their origins and implications.

Distinctions Between Long- and Short-Term Memory Paradigms

Historically, the study of infant visual memory has focused predominately on the development of long-term memory (LTM), thus many of the tools used to assess VSTM grew from this line of research (Caron & Caron, 1969; Rose, 1981). These studies evaluated how much exposure time was necessary for infants to form lasting representations of an object or a given scene (Colombo, 2001; Nelson, 2008). For example, in 1973 Fagan and colleagues demonstrated that infants as young as 6-months old could form lasting memory representations for up to two weeks. In their experiments, infants were repeatedly exposed to an object for a period of up to two-minutes, and at a two-week follow-up test, each infants' preferences to look towards or away from that item were recorded. Infants consistently demonstrated a familiarity preference as they consistently looked towards the item that they had initially been exposed to (Fagan, 1973).

In a later but equally foundational study, researchers, Hunter, Ross and Ames (1982) sought to further understand the role of familiarization compared to habituation by testing groups of 12-month-old infants. Infants in both groups were provided with an array of 3-D toys and objects that they were allowed to manually manipulate. The first group of infants were allowed to play with the items until they were deemed habituated (manipulation of the items was reduced to less than half of what it had been in the first minute for a sustained period of time; ~2minutes). Another group was interrupted shortly after their introduction to the objects and the objects were removed by the experimenter. Then, following a brief period without toys, infants were presented with two arrays of toys and their toy preference was recorded based on first touch preference. The group that had extended periods of familiarization to the point of habituation consistently preferred to look towards and manipulate the novel items, whereas infants who had been interrupted and not had ample familiarization time consistently preferred the objects they had previously seen (Hunter et al., 1982). This led to an understanding that when infants are not given ample time to form a lasting mental representation of an item, they prefer more experience with it, perhaps to better understand that object before moving on to the next.

This line of inquiry into novelty preference piqued the interests of fellow researchers, who sought to understand the development of novelty preferences in 4.5-month-old infants (Roder et al., 2000). In this study, infants were seated on their caregivers' lap in front of a projector screen. Images were presented on the screen, and infants looking behaviors were hand-coded. Each infant was assigned one of three categories of images (faces, complex objects, or abstract kaleidoscope images). Each category contained a set of images, one of which was chosen to be the familiarized item. At the start of experiment, infants were shown a single item. Following the initial presentation, each infant completed 14 paired comparison trials. Trials lasted 3 seconds and began the moment the infant fixated towards the screen. During each trial, the familiarization item remained constant, while a novel item was paired with each new presentation. There was an interval of 1-2 seconds between each trial. Similar to studies mentioned previously, as a group, infants demonstrated a familiarity preference prior to the formation of a novelty preference. Compared to previous studies, this was one of the first to assess individual differences in preference formation. Specifically, at the level of the individual infant, preference formation abruptly transitioned from familiar to novel. Lastly, they also state that the formation of memory representations is not an all-or-one response, nor does it develop in a linear fashion; infants may go from familiarity preference, to novelty seeking and back depending on the stability of a specific mental image (Roder et all., 2000). Given that preferences appeared to switch abruptly within the course of a single task, this provided support for the notion that the eye movements of infants as young as 4.5 months are influenced by the information stored within VSTM after exposures of only a few seconds.

While the preceding studies demonstrate the formation of novelty and familiarity preference following longer visual experience, they also operate under the assumption that infants required lengthy periods of familiarization in order to demonstrate a change or novelty preference. As the foundation of infant visual memory research was grounded in the study of LTM, it should come as no surprise that methods like familiarization and systematic habituation used for studying LTM were also utilized in the early studies of VSTM (Blaga & Colombo, 2006; Fagan, 1973, 1984; Fisher-Thompson, 2014). However, this line of research has been essential to debunking the "common knowledge" that infants do not form lasting memory representations and was pivotal to both our understanding of infant memory development and methods for studying memory (Rose et al., 2001). Although these tools are useful for assessing LTM, they may fall short when it comes to measuring VSTM.

Given the distinct features of VSTM compared to LTM, including limited capacity and rapid decay (Baddeley & Hitch, 1974; Hollingworth et al., 2013; Logie, 1995; Nelson, 2008; Zhang & Luck, 2009) measures that allow infants to view an object for several seconds might in fact probe at fundamentally different mechanisms than VSTM alone (Buss et al., 2018; Ross-Sheehy et al., 2003). Further, according to a 2004 review by Cohen, these tools do not allow for an unfettered examination into of VSTM, as the increased exposure times lead to stable mental representations, thus are tapping into more than just VSTM. While useful in some contexts, they fail to provide insight into the brief, and perhaps more holistically representative exposures to objects that infants encounter throughout their daily lives and across development (Cohen, 2004).

Change Detection and Preference Formation

In an attempt to reduce the influence LTM mechanisms in the study of VSTM, some researchers turned toward change-detection paradigms, where looks toward novel items are taken as indicators of both preference and the formation of a mental representation in VSTM. In these paradigms, subjects are given a set time to view a set of items, followed by a brief delay commonly referred to as a retention interval, followed by a test array where one or more items have been replaced with new items. Frequently, subjects are tasked with identifying the items that have changed either through explicit measures like button-presses or more implicit measures where their looking to the change items more frequently (Bays & Husain, 2012), more quickly, or for longer periods of time. These types of tasks are very useful when it comes to assessing the capacity limitations of VSTM. While capacity cannot be measured using the paired-choice measures, they do facilitate an understanding of the VSTM load infants are capable of maintaining across different age groups.

Tasks involving the presentation of multiple items have been used to test VSTM capacity in order to determine if VSTM exists early in the first months of life and how VSTM capacity changes across the first postnatal year (Rose et al., 2001; Ross-Sheehy et al., 2003). For example, researchers performed a longitudinal study of infants at 5, 7, and 12-months of age (Rose et al., 2001) to probe VSTM changes across these time periods. At each visit, infants participated in a series of 10 trials. Infants were seated on their parents lap while their attention was oriented towards the presented objects. For the 5- and 7-month old infants, they were given 10s of viewing time, but only 3s at 12-months of age. To measure a maximum capacity of 4 items, familiar and novel items were paired with each other and sets that would test spans of 1, 2, 3, and 4 items were created. Following the familiarization period, infants were presented with a test lasting 10s where both familiar and novel items were presented. For example, if testing the span of a single item, the assigned familiar item would be held in front of the infant for 10s, followed by a test where both that item and a novel item were presented sequentially. If measuring a span of four items, each familiar object would be presented sequentially, followed by paired comparisons of each presented familiar item and its assigned novel alternate. Their looks were coded to assess both capacity and recency effects, two well-known STM effects (Oakes et al., 2013; Oakes, Ross-Sheehy, 2007). They determined that capacity does in fact increase in the first year, but that infants at 5-months old show a change preference (they look more towards the novel item at test) with only 1 item, while about half of the infants at 12-months were able to retain as many as 3 or 4 items (Rose et al., 2001).

While interesting, it's possible that the relatively long familiarization intervals (i.e., 3 and 10 seconds) may have been sufficiently long to allow the encoding of the objects into LTM, thus making it less likely to be measuring strictly VSTM capacity. To begin to address this, Ross-Sheehy and others (2003) developed a method of assessing the development of VSTM capacity in early infancy that shared many characteristics with adult change detection tasks (Hollingworth & Luck, 2009; Vogel et al., 2006; Woodman & Luck, 2007). For example, to prevent long familiarization times that allowed infants to form LTM, arrays of stimuli blinked rapidly on and off (500ms on, 250ms off, 500ms on, etc.). In addition, to maximize power, a paired-comparison procedure was used, such that two arrays of blinking colored squares were presented, one on the left, and the other on the right. On one display, the colors of the squares remained the same from blink to blink (no change), and on the other display, the color of a different randomly chosen square changed every blink (change). If infants looked significantly longer to the change display, change detection was inferred (Ross-Sheehy et al., 2003). Using this basic paradigm, the authors demonstrated that 4- and 6-month-old infants could only detect the change for 1-item arrays, whereas 10- and 13-month-old infants could detect the change for up to 4-item arrays indicating an enormous shift in the development of VSTM during this time (Ross-Sheehy et al., 2003). This study is important, as it is the first to demonstrate that infants as young as 4-months do in fact have a functional albeit limited VSTM system and should be capable of performing tasks that may require similar VSTM load.

In the years that followed, there have been several replications and extensions of this basic task. Infants ranging from 6.5 - 12.5-months old have consistently demonstrated the ability to form mental representations in VSTM for location and shape (Oakes et al., 2006), illustrating that significant improvements occur in this system between these times periods and suggested that infants' capacity to bind features of multiple items could be dependent on focused attention (Oakes et al., 2006, 2009). Additionally, cued change detection tasks have revealed that at 10-months, change detection is increased when infants are provided with simultaneous spatial-cues, whereas infants at 5-months recognize the change only when dynamic pre-cues are used, indicating that infants younger than 6-months are capable of encoding information about individual objects independent of one another when arrays of multiple items are presented (Ross-Sheehy et al., 2011). Collectively, these studies indicate that infants are capable of forming mental representations in VSTM in as little as 500ms, and that attention plays a role in the ability to detect change and form mental representations of objects (Oakes et al., 2006, 2007, 2009; Ross-Sheehy et al., 2003, 2011).

In their 2013 study, Oakes and colleagues developed two change detection tasks to assess VSTM in 6- and 8-month old infants using an eye-tracker. They constructed a modified paired comparison task where infants were presented with two items for 517ms, followed by a retention interval of 317ms, and a 3000ms test (Figure 1). The timing, location, and shapes were identical in both experiments. During the encoding presentation, two squares were presented in two different colors, and at test the color of just one item was changed to a novel color. They found that 8-month old infants, but not 6-month-old infants, identified the changed item at test, as demonstrated by longer looking times. In their second experiment, both items in the encoding array were the same color, and at test, only one item changed to a novel color. With this manipulation to the encoding array, 6-month-old infants were able to successfully identify the changed item. Taken together, this indicated that infants at 6-months old were capable of detecting change when enough features remained constant between encoding and test, but that these representations were sensitive to changes in location for younger infants (Oakes et al., 2013).

In a related study (Mitsven, et al., 2018) researchers used a change detection task to probe the connection between VSTM and looking preference formation in 10-month-old infants. Two experiments were conducted using 10-month-old infants (Figure 2). At the onset of each trial, a single colored circle was presented at the center of the screen for 500ms, followed by a retention interval lasting 300ms. At test, two circles were presented equidistant from the center (across the vertical, horizontal, or diagonal axis) for 2000ms. The test array included one circle that matched the memory array, and one nonmatching or novel circle.   Primary measures included direction of first fixation (novel or familiar) and duration of looking to each test item. Results revealed that infants were significantly more likely to orient first towards the novel item, and looked significantly longer overall to the novel item. Importantly, these results demonstrate that 500ms is sufficient time for 10-month-old infants to form a VSTM representation, and additionally, that holding an item in VSTM biases attention toward non-matching items (Mitsven et al., 2018).

While these studies aided in an understanding of how VSTM influences preference formation as it pertains to preference and overall looking time, they fail to address the role of biased competition on reaction time. As previously discussed (Hollingworth et al., 2013), evidence of a biased competition effect has been demonstrated using reaction time with adult subjects orienting faster towards items retained in VSTM. These particular experiments did not assess whether a similar effect could be found in infants as well. Thus, the question still remains if biased competition plays a role in reaction time for infant VSTM, which would in turn indicate early development of connections between basic oculomotor function (e.g. orienting) and VSTM. Further, as these effects were demonstrated in 10-month-old infants, similar research has not been conducted using much younger infants, despite indicators that infants as young as 4.5 months are capable of retaining at least one item (Ross-sheehy et al., 2003).

Purpose and Hypotheses

The ability to form mental representations across the first year of life develops rapidly (Oakes et al., 2013; Ross-Sheehy et al., 2003; Ross-Sheehy & Eschman, 2019). Research has clearly indicated that these mental representations are sufficient to drive a novelty preferences in infants as early as 6-months (Kwon et al., 2014; Mitsven et al., 2018; Oakes et al., 2013). Given this background, the objectives of the current project are two-fold: 1) investigate the prevalence of the biased-competition effect across 5- and 11-month-old infants, and 2) determine if manipulating encoding durations elicits meaningful differences in biased competition effects.

Additionally, if objects held in VSTM have the ability to influence processing speed and attention similar to the effects seen in adults, it is anticipated that infants will demonstrate faster reaction times to familiar items when tested. Alternatively, if competition is in fact biased towards novelty when a stable mental representation is formed, this should be evidenced in faster reaction time and increased looks towards the novel item. In order to address these questions, preference and reaction time will be analyzed.

CHAPTER III: EXPERIMENT 1

Background

Based on previous research, we know that infants are capable of forming memory representations very quickly, and that these memory representations are very sensitive to changes in features like color and location. If infants can in fact build these memory representations rapidly, then it is expected that they should orient quicker and more frequently toward the familiar stimuli than the novel. In the event that VSTM alters orienting speed to familiar or novel items in infancy, this would indicate that higher-level cognitive processes may influence simple eye movements much earlier than previously believed.

Participants

The sample for Experiment 1 included 52 infants, 26 5-month-old infants (*M*=22.29 weeks, *SD*=1.08, 11 females and 15 males), 26 11-month-old infants (*M*=48.26, *SD*=.60, 13 females and 13 females). All infants were born >36weeks gestation (*M*= 39.05 weeks, range = 36 – 41.4weeks), and had typical gestational weight for their age, (*M*= 3437.92g, range = 2494.76 – 4479.22g). An additional 27 infants were tested but were ultimately excluded from the sample if they failed to participate in a minimum of 18 trials, due to disinterest (n=8), fussiness (n=14), or experimenter error/poor calibration (n=5). All parents were high school graduates, and 67.31% of parents had completed a four-year degree or higher. Of the 52 infants, 4 were African American, 2 were Asian, 1 was reported as Hispanic/Latino and the remaining 45 were Caucasian. Three parents selected that their child was Hispanic/Latino. Parents were asked to report birth complications and all infants had no major birth complications and were free from any known health issues at the time of their participation. Parents were contacted through email and phone to inform them of the study and schedule an appointment. Infants were given a small, age-appropriate toy or t-shirt for their participation.

Apparatus

An Eyelink1000+ eye-tracker recorded infants gaze at 500Hz and simultaneous video recording was collected at 30fps. All images were presented on a high-performance 24in., 120Hz Asus monitor (resolution 1920x1080) with a viewable surface of 45.5° (w) and 26.76° (h). Per the manufacturer's (SR-Research) recommended set-up, the eye-tracker was fitted with a 16mm lens and 890nm infrared light emitter. Point of gaze was recorded monocularly using the left eye. A dynamic five-point calibration and validation sequence were presented prior to the onset of the experiment. The eye-tracker and monitor were mounted in front of a solid black curtain. During the task, infants were seated on their caregivers' lap approximately 65cm from the display monitor in a dimly lit room. Parents were asked to not intervene or redirect their infants' attention.

Stimuli and Procedure

Infants were presented with numerous trials that each included a memory, retention, and test display (Figure 3.). All objects throughout the task were presented on a grey background. Before each trial began, a white dynamic star with a smiling face was presented at the center of the screen and accompanied by a musical recording. Following a 100ms fixation on the attention-grabber, the trial began. All objects were created from a pool of 9 unique shapes (circle, diamond, flower, heart, leaf, crescent, snowflake, star or blob) and 9 colors (blue, brown, cyan, yellow, pink, purple, red, green, and orange; see Table 1 in the appendix for RGB values). Infants viewed a maximum of 20 blocks, each consisting of 6 trials, and the colors and shapes were drawn at random at the start of every block. Location of the novel item was counterbalanced within the block, so that the novel item would appear equally on the right and left sides of the screen. The *memory display* consisted of a single item presented at the center of the screen (approximately 7.2°x7.2°) for 500ms. Following the memory display was a *retention interval*, consisting only of a blank grey screen lasting 300ms. Lastly, each trial concluded with either a single- or double-item test. Across both the single and double item conditions, objects presented were 8.67° to the right or left of the center, and approximately 3.57° x 3.57°. Familiar items were identical in both shape and color, while novel items matched only in shape but were presented in a new color chosen from the pool. Thus, in the single-item test, a novel *or* familiar item was presented on the right or the left of the screen (counterbalanced for side of presentation). In the double-item test, both a novel and familiar item appeared simultaneously. The test display remained for 1000ms before returning to the attention grabber.

This task utilized a 2 x 2 x 2 design in which probe type (novel vs. familiar) and condition (single vs. double) were manipulated within subjects, and age (5- and 11-month-old infants) as a between subjects variable. Infants viewed a maximum of 20 randomized blocks of trials, with each block including one of each possible condition (i.e. single-familiar item presented on the right and left, single-novel item presented on the left and right, and double-item tests with the familiar item appearing once on the right and once on the left). Infants were excluded from the final analyses if they did not complete a minimum of 18 trials due to fussiness or disinterest, although on average they completed 43 trials. Frame by frame video coding of infants looking behaviors were performed by expert coders for confirmatory analyses, while 5 infants were excluded from these analyses as frame by frame videos were not available. The primary dependent measures were reaction time for first fixation to one of the test probes, and look type (familiar or novel).

Results

To evaluate the effect of condition on reaction time, a 2x2x2 within subject ANOVA was performed, with Condition (single, double) and LookType as within subjects variables, and age (5- and 11-months of age) as the between subjects variable. This analysis yielded a main effect of condition with looks in the single-item condition yielding significantly faster reaction times compared to the double probe condition, $F(1, 50)=54.307$, $p<.001$. When assessing the effect of LookType on reaction time, we find no significant effect F (1, 50), $p=.940$. Additional within subject ANOVAS revealed that there was no main effect of age; neither age group was faster or slower than the other $F(1, 50) =.502$, $p=.482$. In order to determine if infants of one age group were faster to look towards novel or familiar items, an additional ANOVA was performed and revealed no effect of LookType by Age $F(1,50)=.015$, $p=.902$. When probing an effect of Condition by the LookType, no main effect was evident, indicating that infants across age groups did not have faster reaction times in each condition based on whether they were looking to a novel or familiar item $F(1, 50)=.548$, $p=.463$. And finally, the effect of a three way interaction between Age by Condition by Looktype was analyzed and revealed no main effect, $F(1,50)=.730$, $p=.397$ (Figure 4).

Given these surprising findings, confirmatory hand-coded and analyses were performed using frame by frame video coding. These data ultimately paralleled data collected using the eyetracker, all though the set size was decreased as videos were unavailable for 5 of the 52 infants. A within subjects ANOVA of the hand-coded data was used to evaluate the effect of condition, with Condition (single, double), and LookType (novel, familiar) as within subjects variables, and age (5- and 11-months) as a between subjects variable. Corresponding with the eye-tracking sample, we found a signification effect of condition with infants looking faster in the single-item condition compared to the double-item condition $F(1,44)=24.637$, $p<.001$. Similar to data collected by the eye-tracker, we found no effect of LookType or Age, $F(1,44)=1.406$, $p=.242$ $F(1,44)=.972$, $p=.330$. Additionally, follow-up ANOVAs showed no significant interaction effects of LookType by Age $F(1,44)=.010$, $p=.919$, or of Condition by LookType $F(1,44)=1.269$, $p=.835$. Lastly, when probing the interaction effect of Condition by Looktype by Age, we found no significant effect $F(1,44)=.044$, $p=.835$.

To examine looking preferences as a function of age, novelty preference scores were calculated for each infant (i.e., the proportion of first looks to the novel target probe), and these raw scores were then averaged across each age. Separate one-sample t-tests were then conducted for each age (5 or 11mos) comparing mean novelty preference scores to chance (.5). Surprisingly, results revealed no significant preferences for the 5-month-old infants $t(25)=1.384$, $p=.179$, or for 11-month-old infants $t(25)=1.348$, $p=.190$ (see Figure 5).

Given that infants of both age groups exhibited similar preference and reaction time patterns, age groups were combined. A within subject ANOVA was conducted with Condition (single, double), and LookType (novel, familiar) as within subjects variables and NoveltyPreference (high, low) as a between subjects variable. This analysis yielded no significant effect of Condition by NoveltyPreference $F(1, 50)=.208$, $p=.650$. Additionally, there was no significant effect of Looktype by NoveltyPreference; infants in the high or low groups did not show faster reaction times towards one item or another $F(1,50)=1.210$, $p=.277$. Finally, there was no significant effect of Condition by Looktype by NoveltyPreference $F(1,50)=.198$, $p=.658$.

Conclusion

For Experiment 1, infants of both age groups executed faster saccades to the single-item test compared to the double-item test. This finding was not surprising, given that the single-item condition relied on only a simple orienting response, while the double-item condition may have been more cognitively demanding given the competition between two items. While it is not surprising that infants were faster to execute eye movements in the single probe condition, it is surprising that 11-month old infants were not faster overall compared to 5-month old infants, given that in general the closer an infant is to their first birthday, the faster their reaction time becomes (Ross-Sheehy, 2013). Traditional methods of eye-tracking often included hand-coding, where eye movements are observed by a trained observer and recorded, either live or through video recordings. Confirmatory analyses using video recordings was conducted in order to validate data collected by the eye-tracker, and revealed similar effects.

In general, we found no significant effects of novelty preference for either age group. This was quite surprising given that similar studies with 10-month-old infants have demonstrated that infants display a novelty preference (Mitsven et al., 2018). We anticipated that a similar preference formation pattern would occur in this experiment and that this effect would lead to subsequent differences in reaction time in the double probe condition. Additionally, adult literature has suggested that the contents of VSTM do in fact alter the reaction time when a single item is presented at test (Hollingworth et al., 2013), though we found no evidence of such an effect in our single probe condition with either age groups. It is possible that the integration of both the single and double probe into one paradigm may eliminate the chances of finding similar effects and that in order to assess these effects, infants would need more time viewing an experiment comprised of only single or double probe conditions.

A preliminary study that utilized a similar paradigm and identical timing parameters but tested infants at 5, 7, and 10-months revealed similar findings implicating biased competition on reaction time and preference formation (Ross-Sheehy, 2013). This pilot research revealed that across conditions, older infants were faster to orient than younger infants. Comparatively, infants in both age group responded similar in terms of orienting time. However, similar to the current study, they found no effect on reaction time in the single item condition for any age group. Additionally, in this sample they found that infants at 7-months demonstrated a novelty preference, while Experiment 1 yielded no significant novelty preference for either age group. In their 2004 commentary, Cohen makes the argument that early in the habituation process and before infants have had enough experience with a familiar situation to truly encode it, that they will often exhibit a null preference (Cohen, 2004). That is when visual experience is not adequate to form a representation within an infant's mind, they may teeter between a familiarity and novelty preference, which can result in a null preference. Further, individual differences in encoding speed across infants may wash out indicators of preference as well.

Based on this theory, and the possibility that infants may be exhibiting a novelty preference in some trials and a familiarity preference in others, increasing and decreasing the duration infants had to encode the initial object should pull out these effects. Additionally, Cohen noted that in order to see an effect, infants must be exposed to a competition during the test array, in which both a novel and familiar item are presented.

Across Experiment 1, infants had a high rate of attrition compared to similar tasks and a large amount (n=22) were eliminated because they failed to meet the minimum number of trials due to fussiness or disinterest in the task. Initially, this could have been attributed to the sequence of experiments infants participated in during their study; the first 17 infants who participated in this task did so after completing 3-4 short eye-tracking studies and nearer the end of their lab visit. The task sequence was restructured, and this experiment was presented at the beginning of the eye-tracking studies. While this did help, infants still appeared less interested in this task compared to others, completely less trials on average.

CHAPTER IV: EXPERIMENT 2

Background

As there was no clear evidence to support a preference effect for either age group or for the single- or double-item conditions, Experiment 2 was designed to parse apart any individual differences in encoding time that may have produced the null preference in the first experiment. Further, as there was no evident difference in the RT to orient towards the novel vs. familiar items in the single probe condition, only the double-item condition was used in Experiment 2. It may be the case that infants were exhibiting a null preference at 500ms, or it may be that some infants showed a novelty preference while others showed a familiarity preference, thus washing out any effects. In order to test this, encoding time was manipulated in Experiment Two, with three possible encoding times. Further, if a particular infant teeters on the formation of a preference in one direction with 500ms of encoding time, we should be able to drive that preference in either direction by significantly increasing or decreasing their viewing time with an object.

Participants

The sample consisted of 48 infants, 24 5-month-old infants (*M*=22.31 weeks, *SD* .74, 12 females and 12 males), as well as 24 11-month-old infants (*M*= 48.47 weeks, *SD*=.89, 9 females and 15 males). An additional 9 infants were tested but were ultimately excluded from the sample due to disinterest (n=2), or fussiness (n=7) as they were unable to participate in a minimum of 18 trials. Infants were born at typical gestation and weight (*M*=39.44 weeks, *SD* 1.15, *M*=3501.16g, *SD*=582.11g). All parents were high school graduates, and 75% had a bachelor's degree or higher. Forty-five parents reported that their child was Caucasian, while 3 reported their child as African American, and 3 as Asian/Pacific Islander. Three were Hispanic, and one parent selected "prefer not to answer."

Apparatus

The testing conditions for Experiment 2 were identical to that of Experiment 1. Infants were seated on the laps of their caregivers approximately 65cm from the eyetracker, and eye-tracking was recorded at 500Hz and simultaneous video recording was collected at 30fps. Parents were asked not to intervene. The calibration process was identical to Experiment 1.

Stimuli and Procedure

The stimuli used for Experiment 2 were identical to those used in Experiment 1 with two exceptions (Figure 6). First, as no key differences between preference formation or orienting reaction time were revealed using the single-item condition, only the double probe condition was used for Experiment 2. Second, during the memory display, infants were presented with three encoding conditions, lasting either 100ms, 500ms, or 900ms. Infants saw a maximum of 20 randomized blocks of trials, and each block consisted of six trials, comprised of one of every trial type, 100, 500, and 900ms encoding durations counterbalanced for left and right familiar probe locations. All colors and shapes were selected randomly without replacement within the block. On average infants completed 49 trials and needed to make an eye movement in at least 18 trials in order to be included in the final sample.

Results

To assess the effect of encoding duration on reaction time, a 2x3x2 within subject ANOVA was performed, with LookType (familiar, novel) and Encoding Duration (100, 500, 900ms) as the within subjects variables and age (5- and 11-months of age) as the between subjects variable. This analysis yielded a main effect of age with 11-month-old infants demonstrating significantly faster reaction time across all encoding durations $F(1, 46)=10.045$, $p<.05$. Additionally, across age groups we found a main effect of Encoding Duration with infants across ages exhibiting increased reaction times as the Encoding Duration increased $F(2, 45) =15.025$, $p<.001$. However, when probing the effect of Memory Duration by Age, no significant effect was found $F(2,45)=.126$, $p=.882$. Further, when probing the effect of LookType to determine if infants across ages were faster to orient towards familiar or novel items, we found no significant effect $F(1,46)=.568$, $p=.455$. To probe this further, an additional analysis examining the LookType by Age effect, revealed that both 5- and 11-month-old infants had similar reaction times to both novel and familiar items $F(1,46)=.556$, $p=.460$. We had hypothesized that increases in encoding time would lead to changes in reaction time to the novel or familiar item, but found no significant effect revealing that infants did not form a significant preference or reaction faster to one item or another as a result of changes to encoding time $F(2,45)=.478$, $p=.623$. And finally, an ANOVA probing the effects of Memory Duration by Look Type by Age was performed and revealed no significant effect $F(2,45)=.145$, $p=.866$ (Figure 7).

To examine looking preferences as a function of encoding duration, novelty preference scores were calculated for each infant (i.e., the proportion of first looks to the novel target probe), and these raw scores were then averaged across each age (see Figure 8). Separate one-sample t-tests were then conducted for each age (5 or 11mos) and for each encoding duration (100, 500, and 900ms) comparing mean novelty preference scores to chance (.5). Results revealed no significant preferences for the 5-month-olds at either 900, 500 or 100ms, $t(23)=1.205$, $p=.240$, $t(23)=.606$, $p=.550$, and $t(23)=-.50$, $p=.621$ (see f, respectively, or the 11-month-olds, $t(23)=.922$, $p=.366$, $t(23)=-1.191$, $p=.246$, or $t(23)=.876$, $p=.390$, respectively (see Figure 9 and Figure 10).

Conclusion

In Experiment 2, there was a main effect of age with 11-month-old infants consistently reacting faster during the test array compared to the 5-month-old infants. This finding maps on to preliminary research that demonstrated that infant reaction time increased with age across 5, 7, and 10-months of age under near-identical testing parameters (Ross-Sheehy, 2013). Given that Experiment 2 included only double probe condition and eliminated the use of the single probe encoding array, it more closely aligned with similar research demonstrated that VSTM did in fact influence looking behavior (Mitsven et al., 2018; Oakes et al., 2013). Surprisingly, we failed to replicate previous research demonstrating such an effect in 100ms, 500ms, or 900ms conditions. Given the failure to replicate previous findings, this indicated that the alternations in the timing parameters may probe at an inherently different neural process, be too difficult for the infants, or that something was fundamentally flawed with the task, and thus infants were not able to encode the presented items. In order to probe any design flaws, follow up analyses into the infants side preference were conducted. These revealed that infants across ages exhibited significant side biases, with 22 of the 48 infants exhibiting a side bias greater than 75%, and 7 of those infants exhibiting a preference greater than 90%. While the formation of a significant side preference was split between right and left, left looks comprised 66% of total first looks across conditions.

Interestingly, we did find a significant effect of reaction time by encoding duration. This indicates the duration of the memory presentation increases, so does the time it takes an infant to orient during test. This may be the effect of attentional inertia, in which longer focused attention towards an item leads to a greater depth of processing and a slower reaction time when an image changes. Additionally, given that Experiment 2 was comprised solely of double item tests, and single probe conditions were excluded, the increase in competition between the two items elucidated the age differences during Experiment 2 that were not evident during Experiment 1.

CHAPTER V: DISCUSSION

These studies, taken together, sought to determine the role of biased competition on VSTM in both 5- and 11-month-old infants. Previous literature revealed that at 8-months of age, infants eye movements are guided by the contents of VSTM after exposures as brief as 517ms (Oakes et al., 2013), and that by 10-months infants will prefer novelty at test when given only 500ms of viewing time with a single object presented on a screen (Mitsven et al., 2018). Further, adult VSTM research reveals that the contents of VSTM bias low-level reflexive orienting saccades that were once deemed impervious to higher-level functions like VSTM and attention (Hollingworth et al., 2013). A preliminary study conducted in 2013 sought to test if such processes existed at 5, 7, and 10-months of age and revealed that infants did not demonstrate faster reaction times in single item conditions, but did find evidence of a novelty preference. The present study aimed to fill these gaps by utilizing a full sample of 5- and 11-month-old infants to determine if biased competition did in fact lead to increases or decreases in both the formation of preferences, and reaction time.

In Experiment 1, the single probe condition was designed to answer the question of whether or not biased competition would influence reaction time. That is, could the contents of VSTM yield faster orienting at test. In the event that infants of either age group did orient faster to a novelty versus familiarity, this would indicate that infants reflexive orienting processes, like adults, were modulated by VSTM. Further, the connection between these processes in adulthood suggests a top-down modulation of VSTM over basic oculomotor function. In the single item condition, we did not find evidence that infants moved their eyes faster to one type of stimulus over another. While this could indicate that pathways between VSTM and low-level visual orienting have not yet formed this early in life, additional analyses that failed to map onto predicted findings suggest that this particular experiment may lack the validity of previous experiments. That said, the adult literature suggesting a relationship between these mechanisms may rely more heavily on explicit attention (Cullen et al., 2010; Hollingworth et al., 2013). Given that adults are explicitly told to attend to the central item, then asked to move their eyes as quickly as possible, their orienting mechanisms may already be activated leading to the increased reaction time to items retained in VSTM. It is more challenging to tap into such processes with infants as this experiment relies only on a more passive viewing experience. In that same vein, while their effect was significant, adults were only approximately 10ms faster to orient to familiar items compared to novel items (Hollingworth et al., 2013). Compared to infants, adult subjects are required to sit very still throughout the course of their study and to move only their eyes and not their heads. If such an effect did exist in infancy, it is possible that the margin of error with infant looking may be too high and such a slight effect would be lost.

The purpose of double probe condition of Experiment 1 was two-fold. First, we sought to replicate previous findings where infants clearly developed preferences based on the contents of VSTM (Mitsven et al., 2018; Oakes et al., 2013). Second, we wanted to see if the information retained in VSTM would lead to differences in reaction time when both a novel and familiar item were competing for attention. We found no evidence to suggest that infants at either age group formed a novelty preference and infants reaction time to the novel items was not significantly faster or slower than looks to the familiar item. This failed to replicate previous research suggesting that very young infants tend to form novelty preferences (Mitsven et al., 2018; Oakes et al., 2013; Oakes LM, Ross-Sheehy S, 2007; Ross-Sheehy, 2013). However, it was possible that given just 500ms of encoding time, infants were on the verge of forming a novelty preference or familiarity preference, and that increasing and decreasing exposure time should push infants into these preference categories.

Interestingly however, we did not find that the older infants reacted faster in either condition compared to the 5-month-old infant, which contradicted pilot research suggesting older infants should exhibit faster reaction times (Ross-Sheehy, 2013). It is possible that the integration of both the single and double item probes may have been over complex, or that when combined lacked sufficient power and that separating each trial type into its own experiment might elucidate preference differences. Given the surprising lack of effects, confirmatory hand-coding and analyses were conducted using the frame by frame video coding of infant eye movements. The purpose of the hand-coding was two-fold: 1) this method has been used in previous studies were looking preferences have been demonstrated in infancy and 2) they confirm the validity of our data obtained using our eye-tracker.

Additionally, our rate of attrition for Experiment 1 was very high, with more infants failing to meet the minimum number of trials necessary due to high fuss-out or failure to participate in the task (looking away from the screen, failing to move their eyes at test). This may have been due to the nature of the study itself, and that a more dynamic presentation would have facilitated greater engagement. Additionally, this task was presented among a series of brief eye-tracking studies, and the first 17 subjects who completed this task did so at the end of their lab visit, following 3-4 other eye-tracking studies. Following the high rate of attrition, this experiment was moved to the top of the protocol and the remaining infants viewed this task at the beginning of their visit prior to moving onto subsequent experiments. Nevertheless, infants holistically appeared to be less engaged in this study compared to more dynamic infant experiments.

These hypotheses led to the design of Experiment 2. In addition to altering the timing parameters, as no evidence of variation in reaction time for the single probe condition was demonstrated, this condition was eliminated. Additionally, previous research has indicated that in the process of preference formation, infants often show a familiarity preference first, until they have adequately formed a mental representation of an object, followed by an abrupt switch to a novelty preference (Roder et al., 2000). Further, the encoding duration may have produced a null preference result if it was just barely enough to create a mental representation in some instances but not others (Cohen, 2004). I hypothesized that if this were the case, infants who had not adequately formed mental representations by 500ms would demonstrate a familiarity preference at this point, but switch to a novelty preference when given enough time in the 900ms condition. Conversely, infants for whom 500ms had already been enough to form that preference, 100ms would not be enough to encode, and would result in a constant need to acquire more information (familiarity preference) during the test condition. If this were the case, an infant that formed a novelty preference by 500ms was predicted to demonstrate a familiarity preference at 100ms. Thus, Experiment 2 included three possible memory durations (100ms, 500ms, and 900ms) and each trial included a paired comparison, where both the novel and familiar items were presented at test.

In Experiment 2, 11-month-old infants demonstrated faster reaction times across conditions compared to 5-month-old infants. In general, this finding aligns with previous findings suggesting that infants reaction time increases across the first year of life (Ross-Sheehy, 2013), though it was somewhat surprising as it did not align with the findings of Experiment 1, which yielded no significant age effect. In the single probe condition of Experiment 1, all infants demonstrated similar reaction times. Given that half of all trials were comprised of single-item tests that relied only on rapid orienting and did not involve a competition between items, it is possible this may have washed any effect. That said, in Experiment 2, as encoding time increased during the memory display, reaction time increased during the test array. This effect was constant across look types, as neither the 11- or 5-month-old infants demonstrated significantly faster to novel or familiar items across memory conditions. This slower reaction time aligns with similar pilot research and indicates that attentional inertia is playing a role in reaction time (Ross-Sheehy, 2013). As infants in the study spent more time looking at the encoding array, their depth of processing subsequently increased, leading to more competition during the test and a slower reaction time.

A previous study demonstrating that infants formed novelty preferences at 6- and 8-months when presented with objects for brief periods (517ms) supported the development of this particular task (Oakes et al., 2013). While the timing parameters of this particular experiment were similar to the current study, the presentation of memory items did not rely on infants to bind the features of both location and color, as the items presented in the memory array remained in the same locations at test (the right and left sides of the screen), while only the color of an object changed. In both Experiment 1 and Experiment 2, infants would centrally fixate on a single shape, and at test, that shape was presented on the right and left sides of the screen. It's possible that having to when infants were tasked with having to translate the item from the center of the screen to a new location, this impaired the formation of a stable memory representation. However, this does not appear to have disrupted similar research that also relied on infants' ability to retain a single item in one location and recognize that item at test (Mitsven et al., 2018; Ross-Sheehy, 2013). Further, research has found that infants are able to fully integrate both the features and locations of item at 6.5 months of age (Káldy & Leslie, 2005), and thus should have very little difficulty in tracking the change of a single item. With this in mind, it is reasonable to predict that infants at 11-months of age would be able to successfully track the location change in this task given that they can retain the features of the objects, but that the 5-month-old infants are unable to do so. However, we did not find evidence that either age group recognized or preferred the changed item in either Experiment.

Given that Experiment 2 failed to replicate previous findings indicating that infants' preferences are influenced by biased competition, the likely that infants were unable to retain the information presented to them or that a confounding variable existed within the experimental design that was not readily apparent. Despite the blocking structure of the experiment that was designed to ensure that novel items were presented equally on the right and left sides of the screen, infants still demonstrated an unforeseen side bias. It's possible that the design of the experiment led infants to quickly establish a side preference, regardless of whether a novel or familiar item appeared there and that such a preference reduced the likelihood of detecting a novelty or familiarity preference across the experiment. No significant side preferences was demonstrated in Experiment 1. It's likely that if an infant established a side bias early in an experiment, that the single-item conditions would force the infant to orient towards the opposite side of the screen, thus breaking the pattern. In Experiment 2, as all trials were comprised of double-item tests, forcing a look in the opposite direction was not possible.

Additionally, when 10-month old infants were tested in a similar task, the presentation of items were randomly assigned to appear in more locations (e.g. above vs. below, diagonally right vs. left, and to the left vs. right of center) (Mitsven et al., 2018) which would also work to reduce perseverative looking patters.

Future studies are needed to parse apart these potentially mitigating factors. That said, experimental designs that included only the single item may be needed in order to better understand the relationship between VSTM and basic oculomotor function in infancy. Additionally, similar studies that also include the rotation of object presentation about the vertical, horizontal, and diagonal axes may prove essential, as well as the presentation of two items as to not depend on the ability to translate the location of an item from the center of the screen to another location. Nevertheless, these experiments pave the way for future research aimed to further our understanding of biased competition in infancy.

Conclusion

These studies sought to investigate the role of biased competition among two different age groups in the first year of life. The goal was to determine how the formation of mental representations formed after very brief exposures could influence looking behavior and the formation of novelty and familiarly preferences. Given that much of the eye movements infants make during these formative months rely only on basic orienting abilities (Colombo, 2001), one key purpose was to determine if these eye movements are subject to the influence of VSTM, similar to the ways in which adult orienting can be influenced by the contents of VSTM. Further, preference research conducted with older infants (10 – 13 months) has relied primarily on proportion of looking time and first looks to calculate novelty preference. Here, we introduced a novel paradigm, where reaction time to the target item was also introduced. We found no evidence to support the notion that information held in VSTM influences looking to or away from familiar items at 5- and 11-months of age. Research in this area is ongoing and future studies to assess these relationships are needed.

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APPENDIX

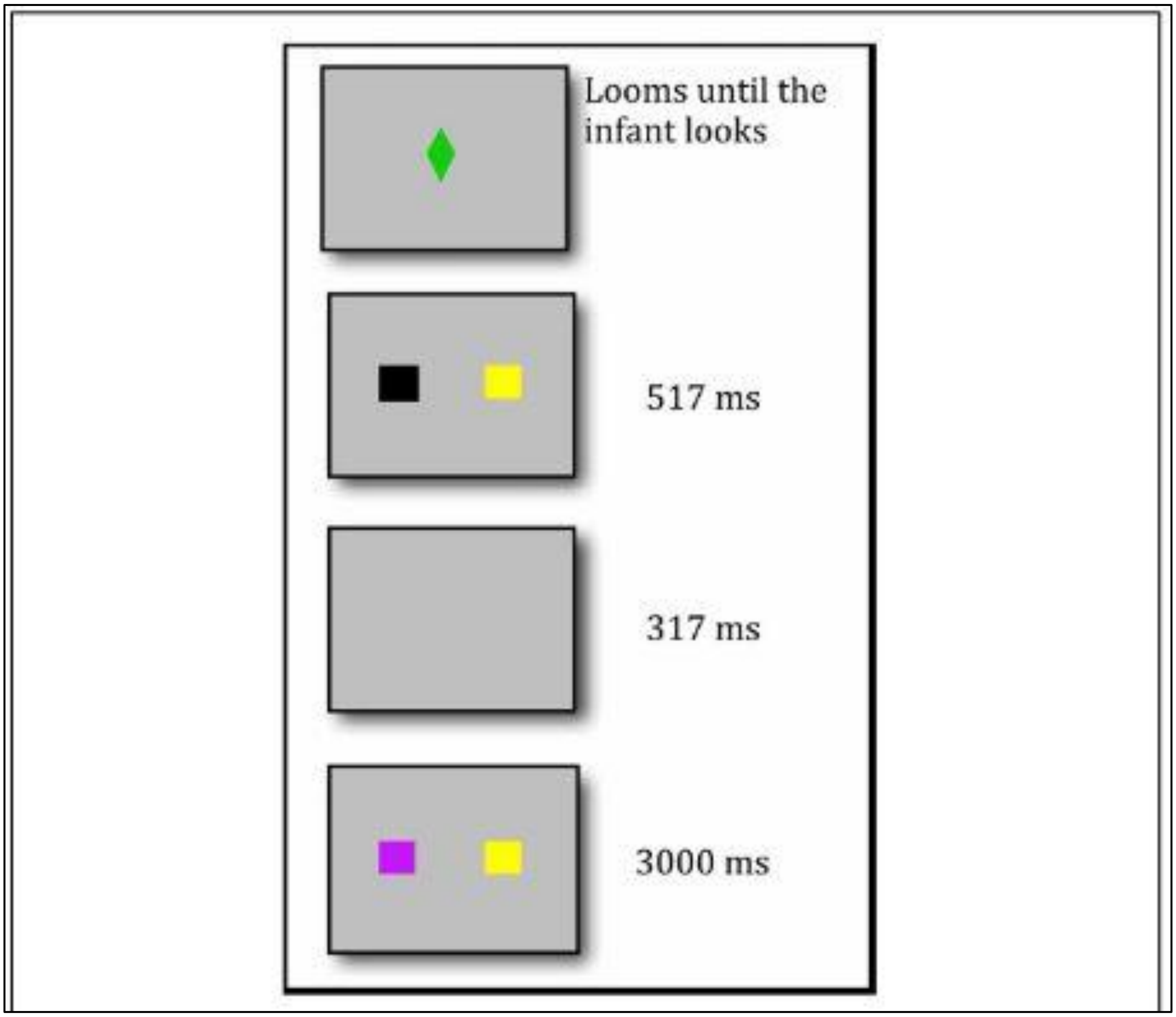

Figure 1: Schematic of Oakes et al., (2013) Experiment 1.

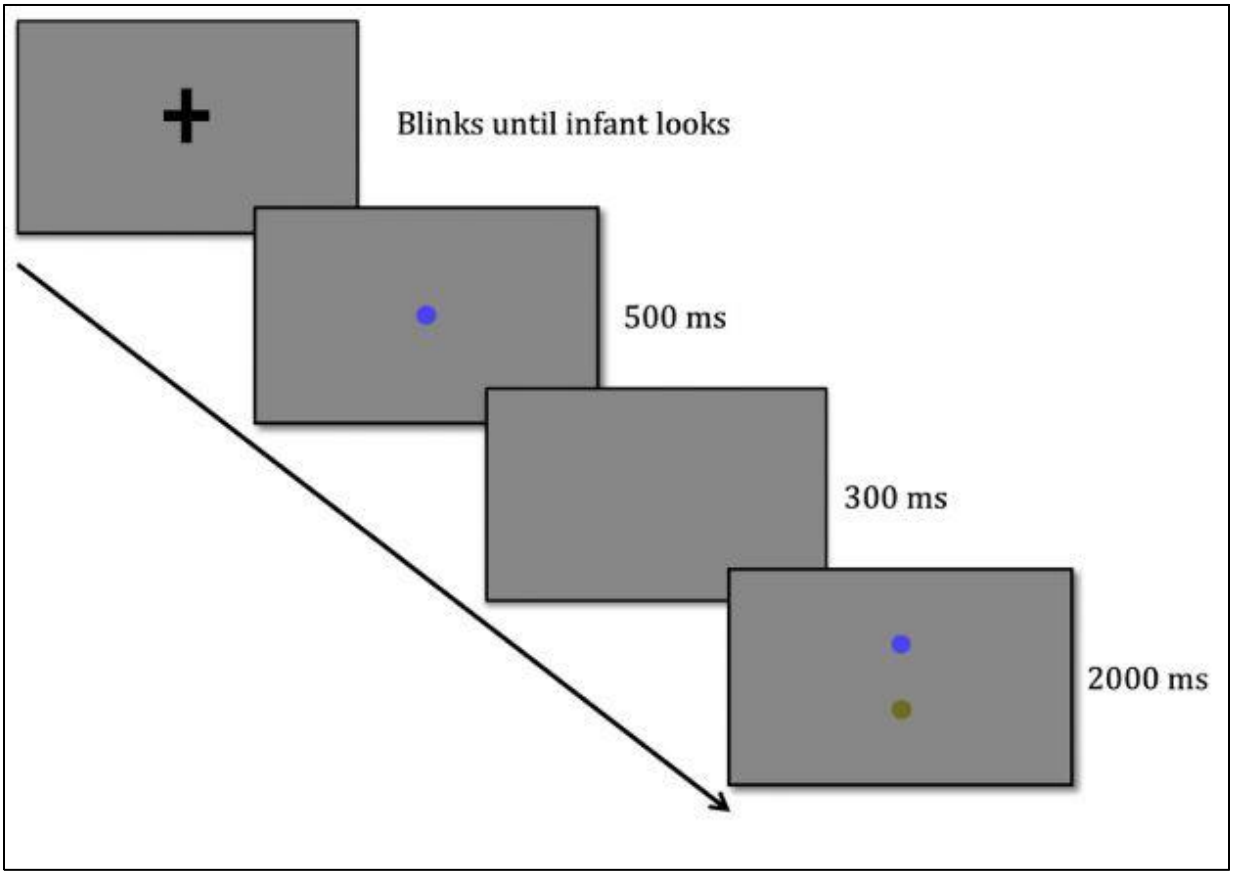

Figure 2: Schematic of Mitsven et al. (2018) Experiment 1.

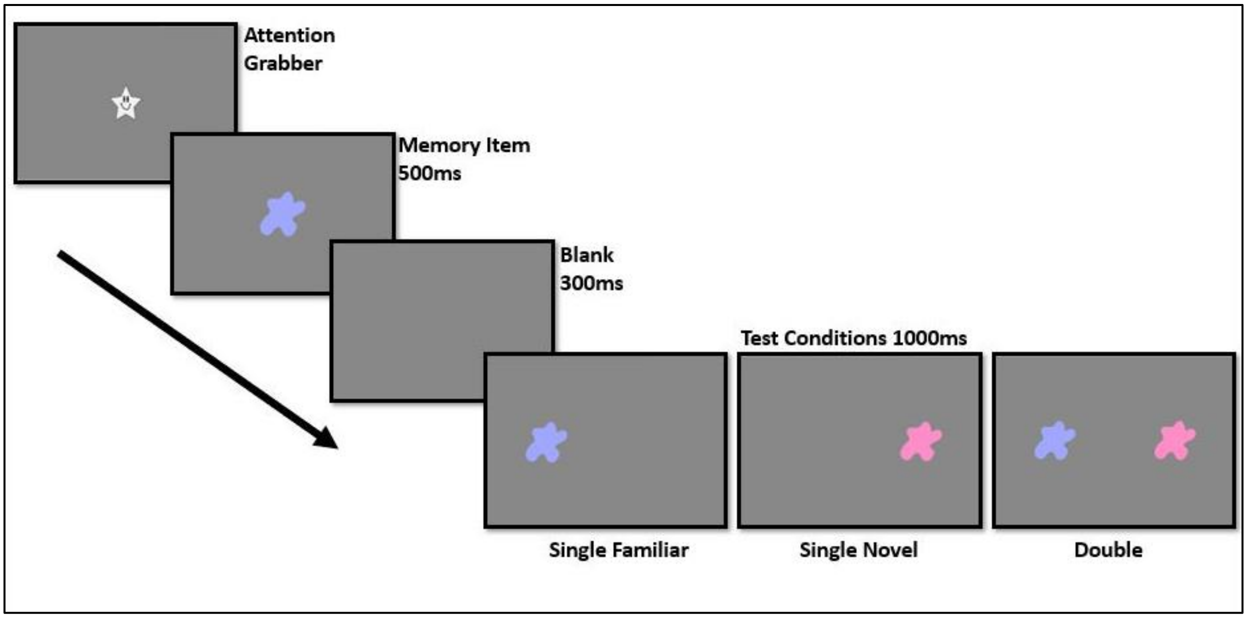

Figure 3. Illustration *of Experiment 1.*

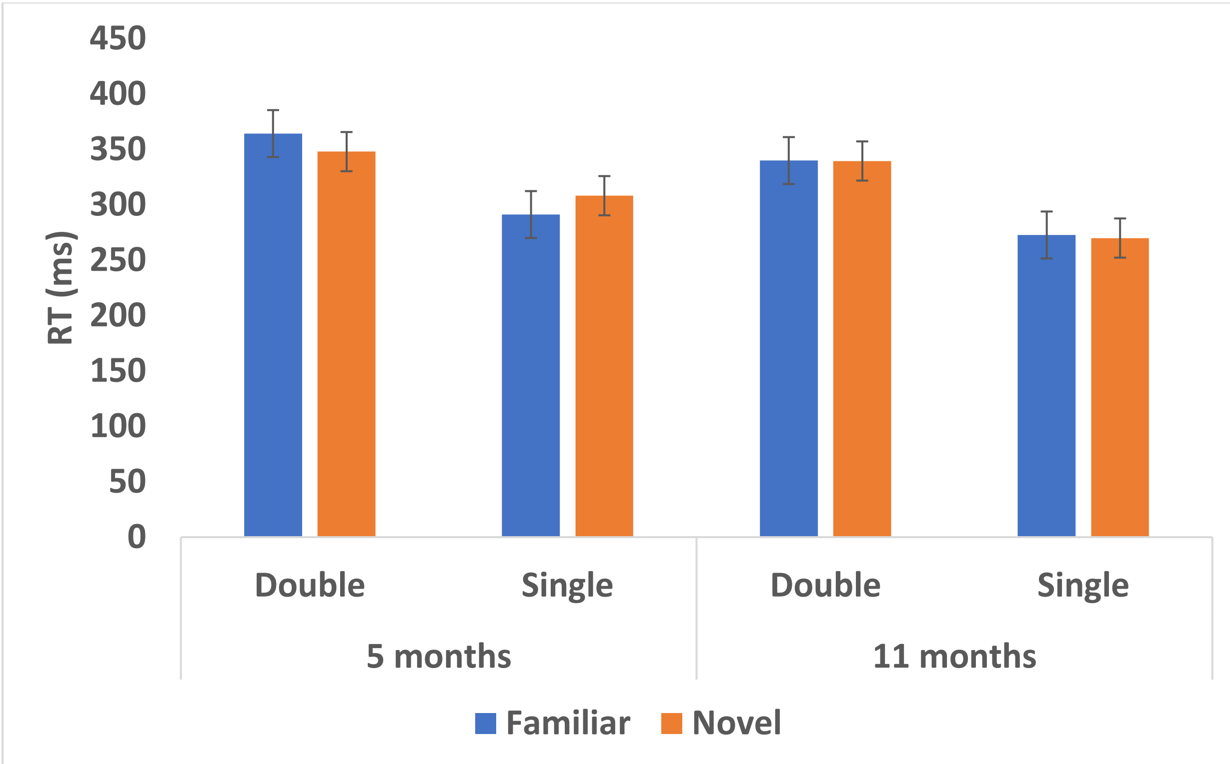

Figure 4. Experiment 1 reaction time by age, condition, and look type, error bars represent +- 1 SEM.

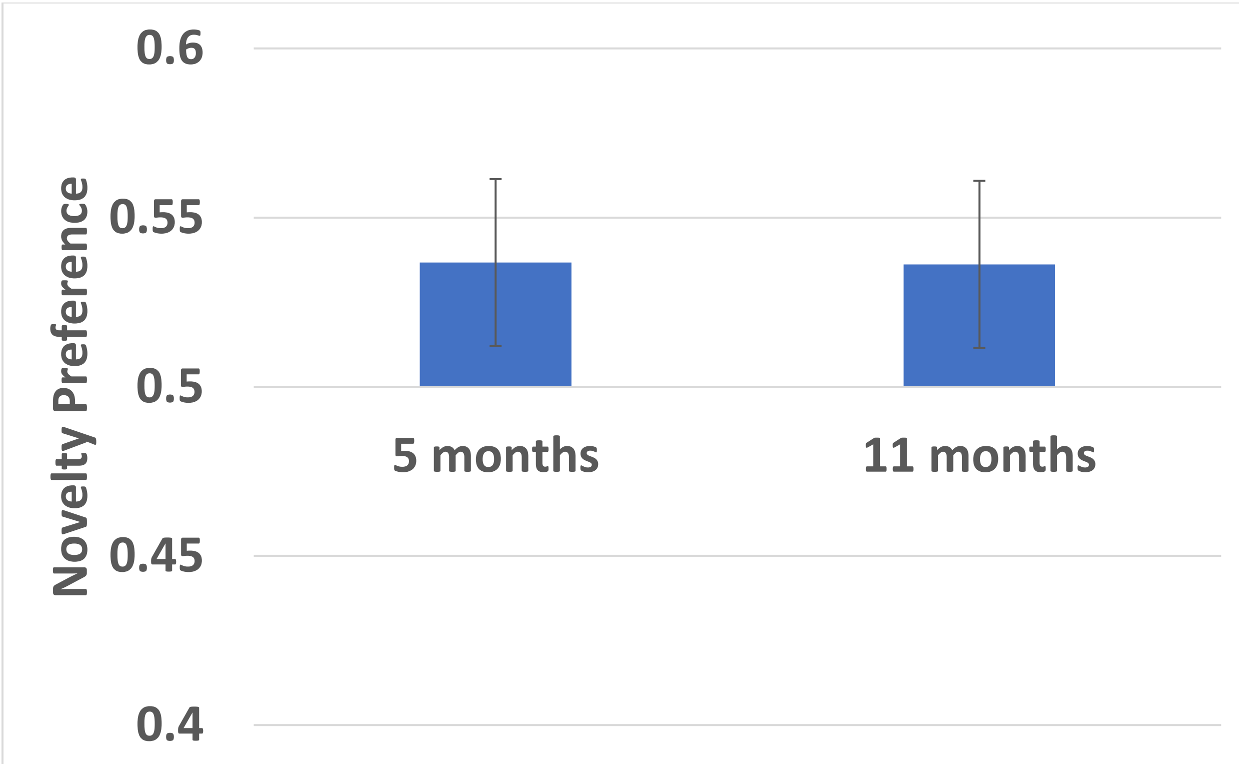

Figure 5. Comparison of novelty preference by age for Experiment 1, error bars represent +- 1 SEM.

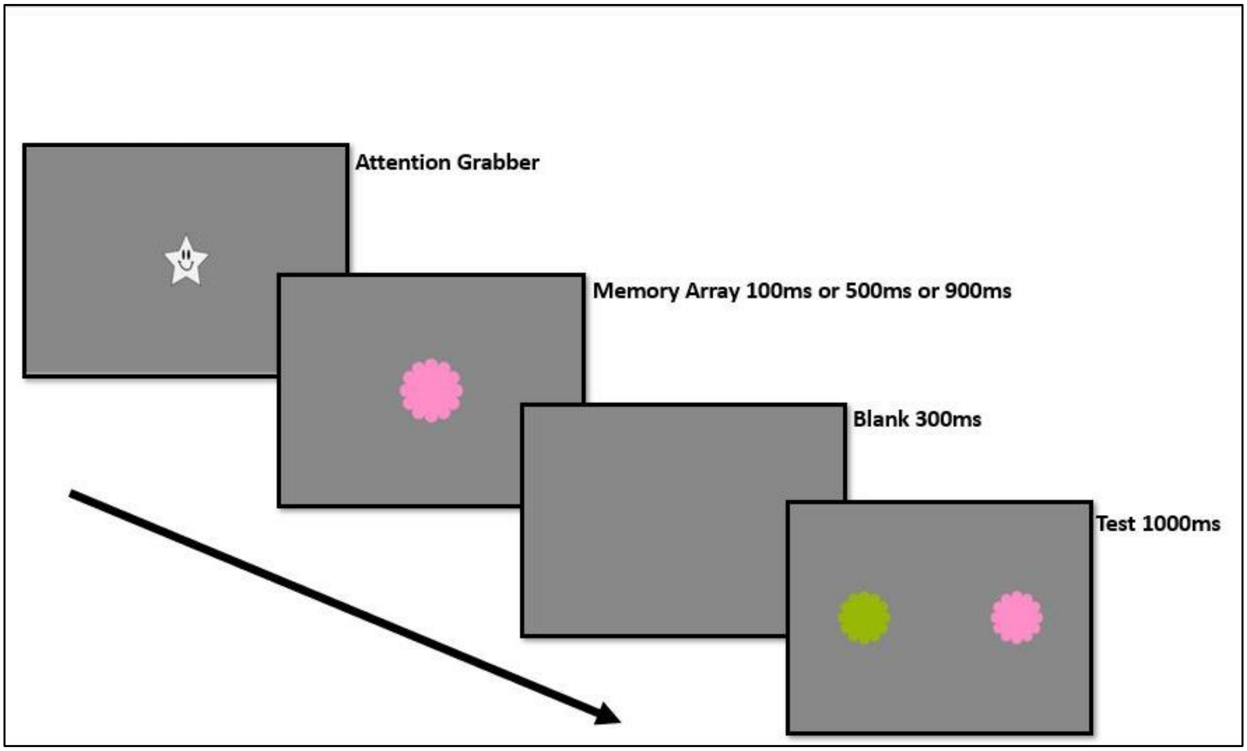

Figure 6. Illustration of Experiment 2.

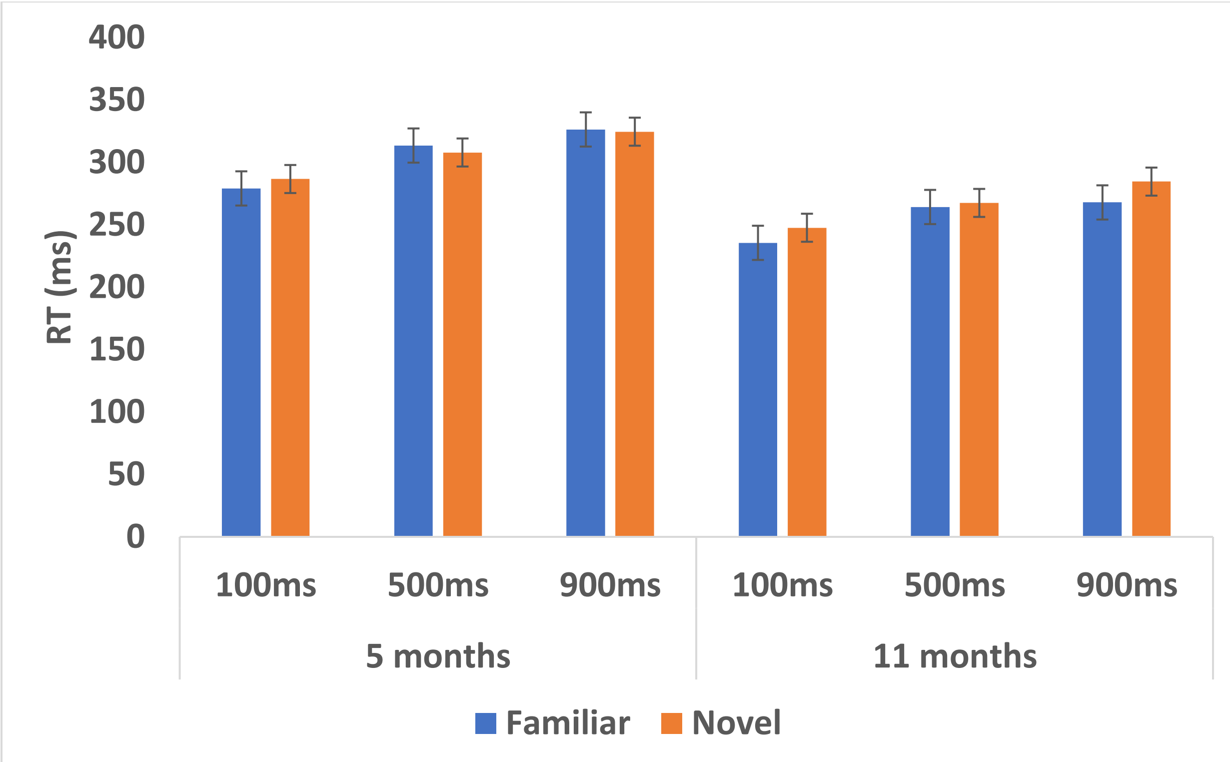

Figure 7. Experiment 2 reaction time by age, condition, and look type, error bars represent +- 1 SEM.

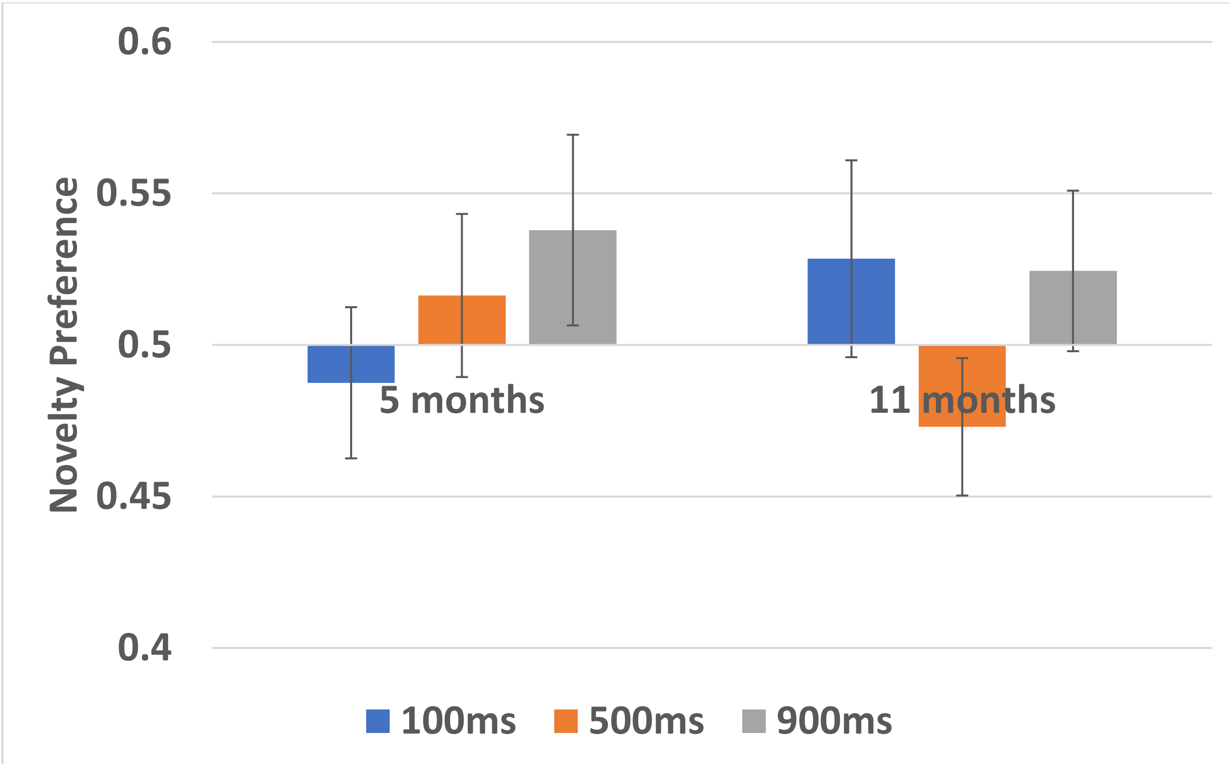

Figure 8. Novelty preference by encoding duration and age group, error bars represent +-1 SEM.

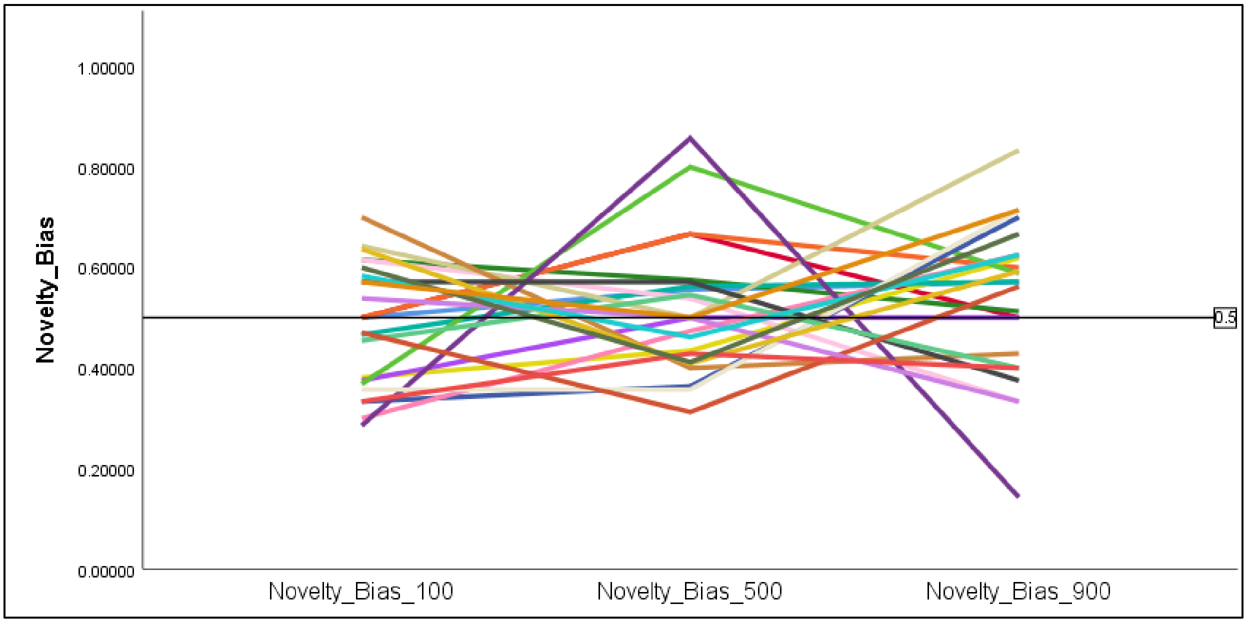

Figure 9. Novelty preference at five months by encoding condition, each line represents each infant's preference score at 95% CI

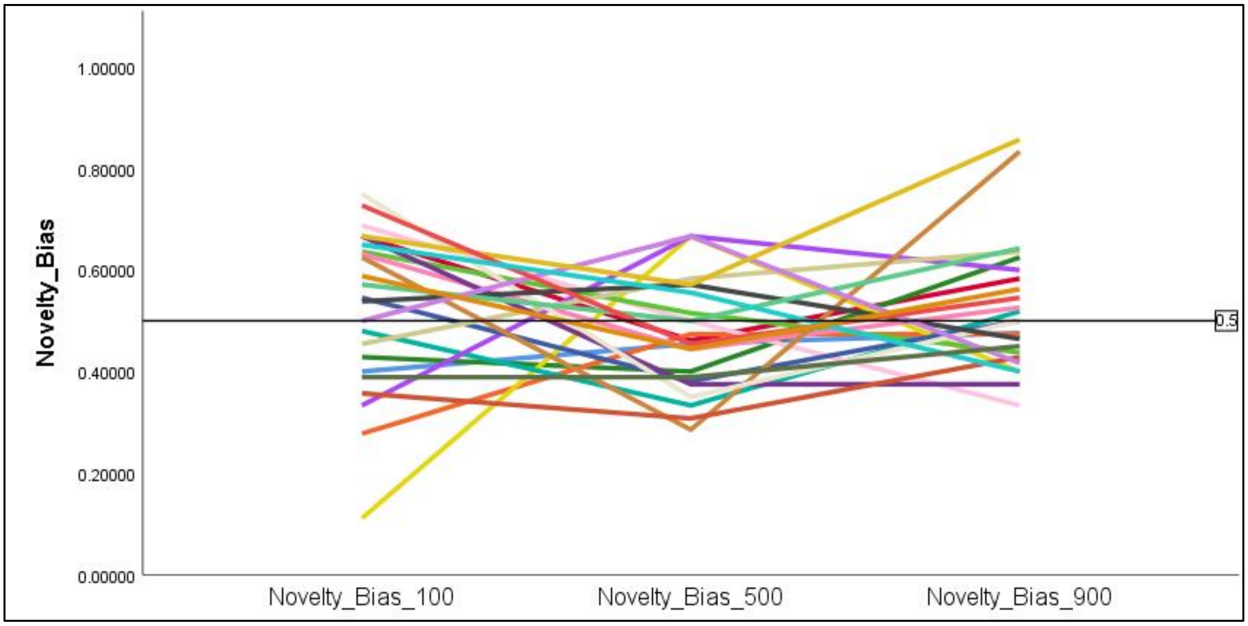

Figure 10. Novelty preference at 11 months by encoding condition, each line represents each infant's preference score at 95% CI.

Table 1:
RGB Stimuli Values

Color	RGB
Background Grey	180, 180, 180
Blue	51, 51, 204
Brown	102, 51, 0
Cyan	105, 255, 255
Green	33, 97, 33
Orange	255, 106, 7
Pink	255, 153, 204
Purple	153, 0, 153
Red	255, 0, 51
Yellow	255, 255, 51

VITA

Amanda Marie Ainsley was born in Hamilton, Ohio and raised in Albuquerque, New Mexico. She is the youngest of five siblings. She graduated Summa Cum Laude from the University of New Mexico where she received her Bachelor of Arts degree in Psychology in 2017.