THE EXAMINATION OF ENDOGENOUS ATTENTION:
STIMULUS-CUE LEARNING IN 4- AND 9-MONTH-OLDS

BY

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Abstract

Through the use of the stimulus-to-response task, the present study tested for the presence of endogenous attention in infants at 4 and 9 months of age. The stimulus-to-response task requires infants to make an internally-driven response, based on the content of a central cue stimulus. Infants were administered a task composed of a *learning phase* and a *test phase*. In the learning phase, they were familiarized with a contingency between the content of a central cue stimulus and the location of a subsequent peripheral target. If infants had the ability to guide eye movements internally, then the learned association between the stimulus cue and peripheral target location could be used to anticipate the location of the subsequent peripheral target. During the learning phase, every trial was consistent with the stimulus cue contingency. During the test phase, trials similar to those in the learning phase were conducted, but "invalid" trials that violated the contingency between the cue stimulus and the peripheral target established during the learning phase were also included. The dependent measures across both phases were latency to the peripheral target and direction of response.

We expected that if infants were using the contingent relationship to anticipate the subsequent peripheral target, latencies of anticipatory responses would decrease across the learning phase. In fact, infants produced shorter latencies across both learning and test phases, but this decrease applied to both correct and incorrect anticipatory responses. This suggests that the increase in anticipations of the peripheral target were not based on the contingent relationship with the stimulus cue.

A similar pattern was observed for the response variable across both variables. Finally, if infants were using the content relationship to anticipate the location of the peripheral target, the introduction of invalid trials during the test phase should have disrupted infants' performance. However, infants at neither age were disrupted by the introduction of the invalid trials. Furthermore, responses on the invalid trials were not consistent with the stimulus-cue contingency.

A secondary issue concerned the salience of the central stimulus within the stimulus-to-response task. When the task has been administered to infants, the salience of the central cue stimulus has consistently been enhanced in order to promote infants' attention to, and retention in the task. The effect of enhancing salience in this task is unknown. In addition to the objectives outlined above, the current study examined this issue through manipulation of cue stimulus salience. It was found that more salient cue stimuli elicited more responses in younger infants. While 9-month-olds' behavior did not vary as a function of cue salience, 4-month-olds' latencies and responses varied, depending on the salience of the cue stimulus. These findings suggest that the enhancement of cue-stimulus salience in this task may differentially affect infants' performance at different ages.

Overall, lack of facilitation of eye movements within this task, based on the contingent relationship, paired with the role of the high salience indicates that infants at neither age showed evidence of endogenous attention. Instead, the evidence from this study shows significant exogenous influence on infants' behavior at both ages tested.

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Dedication

To my parents

Vreau sa va multumesc pentru dragostea si ajutorul care mi l-ati dat.

Fara ajutorul si curajul care mi l-ati oferit, n-as fi putut continua

mai departe cu terminarea doctoratului.

To my husband

I probably would have finished a while ago if I had not met you, but the doctorate would not have meant as much and the journey would not have been as enjoyable.

Thank you for your friendship, patience, encouragement, and support.

THE EXAMINATION OF ENDOGENOUS ATTENTION: STIMULUS-CUE LEARNING IN 4- AND 9-MONTH OLDS

The term *endogenous attention* has recently been proposed (Colombo & Cheatham, 2006) to refer to the interface between attention and other lower-order cognitive processes that presumably give rise to higher-order cognitive functions. Such higher-order cognitive functions have been associated with flexibility, intent, and the ability to generalize to new situations. These functions have been hypothesized to emerge through the ability to select a desired stimuli/response in the presence of robust competing stimuli/response. Thus, endogenous attention reflects the internal control of behavior through the integration of systems, where the desired response/system can be selected while an unwanted response/system is inhibited.

An understanding of the development of endogenous attention provides insight into how functioning systems are integrated within the infants' world and lends awareness to mechanisms that underlie infant behavior. The developmental onset of endogenous attention has been posited to occur in the latter half of the first year of life (Bell, 1998; Colombo & Cheatham, 2006; Diamond, 1990a,b,c, 1991a,b; Ruff & Rothbart, 1996; Ruff & Capozzoli, 2003), and presumably attains adult typology around 7 years of age (Diamond, 2002; Rothbart & Rueda, 2005). Several lines of literature have converged to generate this consensus. Diamond (1990a,b,c, 1991a,b) has shown that the ability to retain information and inhibit a prepotent response starts to develop around 7 months of age; furthermore, she hypothesizes that this behavior is supported by the dorsolateral prefrontal cortex. A similar developmental trend is observed in the measurement of ocular latencies (Colombo & Cheatham, 2006). Ocular latencies notably decrease between 3 to 6 months of age (Blaga & Colombo, 2006; Casey & Richards, 1988; Hood & Atkinson, 1993; Ruff & Capozzoli, 2003), but increase between 7 to 26 months of age (Oakes & Tellinghuisen, 1994; Ruff & Capozzoli, 2003; Ruff, Capozzoli, & Saltarelli, 1996; Ruff & Lawson, 1990). It is hypothesized that the U-shape function provided by ocular latencies represents the end of the development of disengagement and the onset of the development of endogenous attention. Furthermore, this change in the measurement of ocular latencies marks the shift from externally driven visual behavior to internally driven visual behavior. According to this theory of the development of endogenous attention, infants' behavior prior to 6 months of age should not be expressed as internally driven action.

In contrast, some research has suggested that infants' behavior before 6 months of age may be interpreted as being endogenously driven. For example, it has been claimed that 4-month-old infants have the ability to inhibit dominant responses (Johnson, 1995b; Johnson, Posner, & Rothbart, 1994) and use learned associations to guide eye movements in a purposeful manner (Johnson, Posner, & Rothbart, 1991). If infant behavior prior to 6 months of age is internally driven, then the prevalent theory of the development of endogenous attention must be recast to incorporate an earlier onset.

In the early study of infant attention (i.e., birth to 6 months) infants' behavior is thought to reflect external mechanisms and, as such, endogenous attention is often discounted. However, if infants' behavior is internally driven then, endogenous attention must be considered when studying infants' cognitive development. Therefore, the onset of internally driven behavior is highly relevant in understanding infant behavior.

The purpose of this study is to critically examine the possibility that some forms of endogenous attention are present as early as 4 months of age. A brief background of endogenous attention and its development will be discussed, followed by a critical examination of research studies, which indicate internally driven behavior in infants as young as 4 months of age. Finally, the current study will be presented with a thorough examination of its findings and its relevancy for future research.

ENDOGENOUS ATTENTION

The operational definition of endogenous attention remains elusive even in the face of abundant theorizing about the construct (e.g., Desimone & Duncan, 1995; Funahashi, 2001; Miller & Cohen, 2001; Norman & Schallice, 1986; Posner, 1992, 1995; Rabbit, 1997; Smith & Jonides, 1999; West, 1996). For the sake of brevity, each of these theories will not be reviewed; rather, I will note that all of these theories share a few common characteristics.

First, all of these theories propose that endogenous attention is composed of the integration of several lower-order subsystems. Furthermore, endogenous attention is marked by the ability to control the operations of these subsystems volitionally, as well as inhibiting prepotent responses. Thus, endogenous attention is characterized by the control of a set of subsystems and the ability to select a desired action.

The integrative element of endogenous attention has been attributed to the prefrontal cortex, and the dorsolateral prefrontal cortex has been specifically identified in some work (Miller & Cohen, 2001). For example, damage to the prefrontal cortex is related to delay issues and/or deficits in working memory (Funahashi, Bruce, Goldman-Rakic, 1993; Funahashi, Bruce, Goldman-Rakic, 1991; Funahashi, Bruce, Goldman-Rakic, 1989; Quintana & Fuster, 1992; Takeda & Funahashi, 2002; for a review see Funashasi & Kubota, 1994), increased distractibility (Aron, Sahakian, & Robbins, 2003; Birnbaum et al., 2004; Chao & Kinght, 1995; Drewe, 1975; Woods & Knight, 1986), and inhibition problems (Aron, Sahakian, & Robbins, 2003; Blasi et al, 2006; Duncan, 2001; Gaymard, François, Ploner, Condy, & Rivaud-Pechoux, 2003; Gemba & Sasaki, 1990; Pierrot-Deseilligny, Rivaud, Gaymard, & Agid, 1991; Ploner, Gaymard, Rivaud-Pechoux, & Pierrot-Deseilligny, 2005; Sasaki, Gemba, Nambu, & Matsuzaki, 1993; Tsujimoto et al., 1997). Working memory, distractibility, and inhibition are thought to be supported by the prefrontal cortex, and are the same systems that have been attributed to the control and inhibition of action.

Given that endogenous attention is supported by the prefrontal cortex, it follows then that the developmental course of the maturation of the prefrontal cortex should map on the developmental onset of the above-mentioned systems. The prevalent theory of the development of endogenous attention has been established through the measurement of behavior similar to those mentioned above. In line with the prevalent theory of endogenous attention, the onset of metabolic activity in the frontal lobe occurs between 6-8 months of age (Chugani, Phelps, & Mazziotta, 1987) and electroencephalographic activity of the frontal lobe increases between 6-12 months of age (Bell & Fox, 1992, 1994). I will now turn the discussion to the development of endogenous attention through the use of measures related to working memory, inhibition, and distractibility.

The Development of Endogenous Attention

A-not-B/Delayed Response Tasks as Measures of Endogenous Attention

The A-not-B task has been established as a marker for the developmental onset of endogenous attention and has been posited to reflect the integrated output of working memory and inhibition (Diamond, 1990a, b). The task is analogous to the delayed response task from the animal literature, but was developed and popularized for children by Piaget (1954) as a measure of cognitive development. Based on findings and data collected from the animal literature, the case has been made for using the task with infants as a measure of dorsolateral prefrontal cortex maturation or function. In the A-not-B task, the infant watches a toy being hidden at location A. In full sight of the infant, the toy is removed from location A and then hidden at location B. The infant is then allowed to retrieve the toy. Between 8 to 11 months of age, infants attempt to retrieve the toy from location A (not B), even though they saw it being hidden at location B. This type of error is commonly referred to as the A-not-B error.

Diamond (1985) has shown that there is a developmental progression in terms of the infants' ability to perform the A-not-B task over delays. Before 7½ months of age, infants are unable to perform the task even when there is no delay. By the time infants reach 7½ months they can perform the task with a delay up to 2 s. After 7½ months an infant's tolerance increases to a rate of 2 s per month. For infants to successfully perform the A-not-B task they must meet two requirements: (1) they must be able to inhibit the prepotent response to reach for location A, and (2) they must remember the location of the toy over the delay. Both of these behaviors are supported by the dorsolateral prefrontal cortex (e.g., Drewe, 1975; Funahashi et al., 1993; Tsujimoto et al., 1997). Thus, the developmental change in the A-not-B task has been attributed to the development of the dorsolateral prefrontal cortex. Lesions to the dorsolateral prefrontal cortex produces AB errors at delays of 2, 5, and 10 s in adult monkeys, which are similar to the errors found with human infants (Diamond & Goldman-Rakic, 1989), further strengthening the connection between performance on the A-not-B task and the function of the dorsolateral prefrontal cortex.

These results have been replicated with the delayed response task. As mentioned earlier, there is an unequivocal relationship between dorsolateral prefrontal function and the delayed response task (Funahashi, Bruce et al., 1993; Funahashi et al., 1991; Funahashi, Bruce, & Goldman-Rakic, 1990; Funahashi et al., 1989; Funahashi, Chafee, & Goldman-Rakic, 1993; Takeda & Funahashi, 2002). Although the delayed response task was developed and used primarily with monkeys, its use with infants should further strengthen the developmental time course of the dorsolateral prefrontal cortex. If both the delayed response task and the A-not-B task reflect dorsolateral prefrontal function, it follows then that the delayed response task should show a developmental pattern similar to the A-not-B task. According to Diamond and Doar (1989), the developmental time course of the delayed response task is identical to the developmental time course of the A-not-B task.

In summary, both the A-not-B and delayed response tasks show the same developmental progression and similar deficits as a result of lesions to the dorsolateral prefrontal cortex. These findings further solidifying the concept that developmental onset of endogenous attention is thought to emerge in concert with the dorsolateral prefrontal cortex at around 7½ months of age. Additional support for the prevalent theory of the development of endogenous attention can also be obtained through the examination of the distractibility literature.

Distractibility as a Measure of Endogenous Attention

The developmental time course of endogenous attention has also been replicated with the measurement of distractibility, which as mentioned previously, is also related to the function of the prefrontal cortex (e.g., Woods & Knight, 1986). More specifically, individuals with damage to the prefrontal cortex are more susceptible to distraction. Since overt behavior in both the A-not-B/delayed response tasks and distractibility tasks are supported by the function of the prefrontal cortex, it follows that developmental changes in distractibility should map onto developmental changes in the A-not-B/delayed response tasks.

Distraction is generally measured using a paradigm where an infant is presented an interesting stimulus or toy in the central visual field. Once the infant is judged to be engaged with the central stimulus, an attractive stimulus is presented in the peripheral visual field. The ocular latency between the onset of the peripheral stimulus and the eye movement to the peripheral stimulus is the dependent variable. Ocular latencies toward a central stimulus increase between 7 to 26 months of age (Oakes & Tellinghuisen, 1994;

Ruff & Capozzoli, 2003; Ruff, Capozzoli, & Saltarelli, 1996; Ruff & Lawson, 1990), indicating that infants become progressively less distractible.

The observed changes in ocular latencies have been posited to be sustained by the emergence of endogenous attention (for a review, see Colombo & Cheatham, 2006). As expected, the developmental time course of distractibility maps onto the developmental time course of endogenous attention as measured by A-not-B/delayed response tasks. Furthermore, the quality of attention directed toward the central stimulus shows a similar developmental trend. For example, 6-month-old infants are unaffected by novelty and familiarity of a central stimulus, while 10-month-olds are more easily distracted from familiar ones (Oakes, Kannass, & Shaddy, 2002). Distractibility thus appears to be mediated by task demands at the later age; further indicating the emergence of endogenous function. In summary, the distractibility literature lends additional support for the developmental onset of endogenous attention and prefrontal function around 7 months of age.

Early Attentional Control

Given that endogenous attention develops after 6 months of age, what can be said of infants' behavior prior to this point in development? According to the predominant theory of the development of endogenous attention (Bell, 1998; Colombo & Cheatham, 2006; Diamond, 1990a,b,c, 1991a,b; Ruff & Rothbart, 1996; Ruff & Capozzoli, 2003), behavior during the first half of the first year is driven exogenously, and predominantly lacks volition on the part of the infant. However, according to Johnson's maturation hypothesis (Johnson, 1990a,b, 1994a,b, 1995a, 1998), which accounts for the changes in infants' visual behavior in the first months of life by examining the development of cortical function, infants have endogenously-driven behavior as early as 4 months of age. Johnson (1994b, 1995a) hypothesizes that, around 4 months of age, infants show the first indication of endogenous attention via the ability to volitionally select a response and inhibit an unwanted response (Johnson et al., 1991; Johnson et al., 1994). If 4-month-olds exhibit internally driven behavior, then endogenous attention occurs earlier than previously thought and a re-evaluation of the prevalent theory of the development of endogenous attention is required.

The Stimulus-to-Response Task as a Measure of Attentional Control

As indicated earlier, the purpose of this study is to examine the possibility that endogenous attention is present in infants at 4 months of age. Thus, the development of endogenous attention will be critically evaluated through the replication and extension of the *stimulus-to-response task* (Johnson et al., 1991) with 4 and 9-month-olds. The use of the stimulus-to-response task is of particular relevance as a measure of endogenous attention, because of its relation to the function of the dorsolateral prefrontal cortex (Quintana & Fuster, 1992; White & Wise, 1999). In essence, the stimulus-to-response task requires the participant to make a response that is contingent on the content of a central cue stimulus. Research indicates that neurons in the dorsolateral prefrontal cortex are responsible for the ability to perform this task.

Johnson et al. (1991) has reported that 4-month-olds were able to perform a stimulus-to-response task that required them to orient to a particular location in response based on a learned association between the content of a cue stimulus and the peripheral target location. In this study, infants were presented 18 training trials with two varying dynamic multicolored stimuli each with an accompanying beeping sound. Each cue stimulus was associated with a peripheral target that appeared to the left or right of the cue stimulus. The location of the peripheral target (i.e., left or right) was contingent on the content of the cue stimulus. Four-month-old infants had a significant decrease in response time during the training trials relative to the learning trials, suggesting that they were able to use the content of the cue stimulus to facilitate saccades toward the upcoming peripheral target. Furthermore, during test trials, a bilateral presentation of the peripheral target was employed to assess learning. Four-month-olds had a significant mean preference for the contingent side during the test trials, further indicating that they were able to use the content of the cue stimulus to facilitate eye movements to a particular spatial location.

Infants' ability to use the content of the cue stimulus to facilitate eye movements implies the presence of internally-driven behavior. In other words, once infants have learned the association between the stimulus cue and the contingent location of the peripheral target, they are then able to use that association to direct eye movements toward the contingent side; thus, eye movements might be considered to be volitional. However, there are some indications that infants' early (i.e., 3-4 months of age) visual behavior is not necessarily dependent on content, but rather dependent on spatial characteristics.

Clohessy, Posner, and Rothbart (2001) showed that 4-month-olds were able to learn a contingent association, but were unable to learn the association when it was context dependent. Furthermore, Colombo, Mitchell, Coldren, and Atwater (1990) found that although infants ages 3, 6, and 9 months could use both position (i.e., spatial cues) and stimulus (i.e., content cues) cues to learn an association, positional cues were dominant in situations where stimulus content and location were conflated; for older infants, stimulus cues were dominant. In addition, the learning of content cues was particularly transient and fragile in 3-month-olds; learning based on content cues dissipated after a 5-minute delay in these young infants when learning based on position cues was retained or persisted after the same delay (Colombo et al., 1990). Jonides (1981) has shown that spatial cues trigger automatic responses in adults, whereas content cues are associated with endogenous responses. If infants are responding to spatial cues it is likely they are producing an automatic response rather than internally driven behavior.

It is also worth noting that in Johnson et al.'s (1991) study, 4-month-olds showed a 60% mean preference for the contingent side. Although this result was significant, the authors admit that "the contingency learning found in 4-month-old age group is rather weak" (p.342). In addition, Clohessy (1993) did not find a significant mean preference for the contingent side using the stimulus-to-response task. Before the prevalent theory of endogenous attention needs to be reevaluated the stimulus-to-response task must be critically examined. According to Johnson (Johnson, 1990a,b, 1994b, 1995a) the results obtained from the stimulus-to-response task in concert with results obtained from several other experiments support the presence of endogenous attention relatively early in the life span. I will briefly review these experiments and how they relate to the study of endogenous attention.

Expectation Paradigm as a Measure of Attentional Control

A study by Haith and colleagues (Haith, Hazan, & Goodman, 1988) has been cited (Johnson, 1990a, Clohessy, Posner, & Rothbart, 2001) as further support of an early measure of attentional control. Haith et al. presented 3.5 months-old infants with a series of pictures at alternating right/left locations. The results showed that, over the course of trials, infants' response time to the alternating sequence was facilitated. Indeed, in some cases, eye movement occurred prior to the onset of the impeding stimulus; such eye movements were characterized as *anticipations*. The authors suggested that the infants were forming expectations based on the regularity of the situation and were using these expectations to anticipate the upcoming stimulus. Anticipation implies that infants can guide their visual behavior based on their expectations of what is going to occur; thus, they have the ability to anticipate upcoming behavior. This research provides support for endogenous attention.

Other studies have shown that infants are able to process the content of alternating stimuli (Adler & Haith, 2003; Wentworth & Haith, 1992; Wentworth, Haith, & Hood, 2002), can learn sequences when temporal characteristics are removed (Canfield & Smith, 1996), and that over time infants adjust their strategies (Wentworth & Haith, 1998). The aforementioned studies indicate that infants can incorporate multiple items in the formation of expectations.

An alternative interpretation of these data, however, is that infants may not be anticipating based on their expectations for upcoming events, but rather have developed a motor-level pattern of responding to predictable spatio-temporal characteristics of the sequence (Reznick, Chawarska, & Betts, 2000; Rose, Feldman, Jankowski, & Caro, 2002). Infants as young as 6 weeks of age were shown to be able to anticipate the upcoming stimuli using an alternating left/right sequence (Robinson, McCarty, & Haith, 1988), an age at which volitional attentional mechanisms seem highly unlikely (Johnson, 1990a). Therefore, the ability to "anticipate" in the visual expectation paradigm may not necessarily involve all of what is implied by Haith and colleagues' (Haith, 1993; Haith et al., 1988; Canfield & Haith, 1991; Johnson, 1990a) definition of "expectations." Although the visual expectation literature provides some indication of endogenous attention, this literature (like that of stimulus-to-response task) does not provide definitive support for the early development of endogenous attention.

Anti-saccade Task as a Measure of Attentional Control

According to Johnson (1994a; 1995b) further support of volitional control comes from infants' abilities to inhibit a prepotent response, which has been observed with a modified anti-saccade task.

In the anti-saccade task, subjects are cued to a particular spatial location and are instructed to make a saccade away from a cued location. It has been shown that a spatial cue tends to result in an automatic saccade to the cued location (Fischer & Breitmeyer, 1987); thus, to make a saccade in the opposite direction, subjects are required to (1) inhibit an automatic saccade towards the cued location, and (2) to trigger a saccade to the location opposite of the cue. Anti-saccade latencies are longer than regular saccades irrespective of training (Hallett, 1978); most likely, this is due to the time it takes to execute the two requirements of the anti-saccade.

Given that infants cannot be instructed to make a saccade away from a cued location, Johnson et al. (1994) developed a modified anti-saccade task. In this task, infants were trained to look to a location opposite of the cue location. This was done by presenting a spatial cue followed by the presentation of a peripheral target located in the opposite direction relative to the cue location. Latencies during the training phase were significantly longer than in the control condition; and similar to the adult literature, the longer latencies were attributed to the time necessary to redirect attention from the cued location to the peripheral target location. Johnson et al. (1994) concluded that infants' ability to perform an anti-saccade task is indicative of the transition from an automatic responding to volitional control.

Although 4-month-old infants appeared to be able to perform the modified anti-saccade task, it is worth noting that, in this form of the anti-saccade task, the appearance of the peripheral target might be influencing latencies; since the latencies involved did not need to be anticipatory in nature, infants might be simply responding to the presentation of the cue stimulus. The longer latencies might be attributed to mechanisms related to the ocular system rather than to the existence of endogenous attention. Thus, performance in the modified anti-saccade task alone is not enough to conclude that volitional control is present at 4 months of age. However, in concert with the stimulus-to-response task and the visual expectation paradigm, the results obtained from the modified anti-saccade task indicates further the need to examine the presence of endogenous attention around 4 months of age.

If, in fact, 4-month-old infants possess attentional control, the prevalent theory of endogenous attention needs to be recast with the new developmental onset. In addition, endogenous attention must be taken into consideration when studying early infant attention. However, before a reevaluation of the predominant theory of endogenous attention is warranted, it is imperative that the stimulus-to-response task be replicated with 4-month-olds. Furthermore, when studying the development of attentional control, there is a methodological matter that needs to be taken into account.

Methodological Considerations

In the adult literature, endogenous and exogenous shifts of attention are distinguished operationally through the use of spatial and content cues. The two cues vary primarily in the location of their presentation. More specifically, spatial cues appear at the location of the peripheral target, while content cues are centrally located and visually indicate the location of the peripheral target (e.g., arrows). Spatial cues have been shown to trigger automatic or exogenous responses, whereas content cues are associated with endogenous responses (Jonides, 1981). It follows that, within the realm of infant attention, the same distinction between exogenous and endogenous responses can be made through the use of spatial and content cues.

The use of spatial cues requires no change in protocol; however, this is not the case with the use of content cues. The stimulus-to-response task was developed for use with subjects who are incapable of being directed to use the content of the cue to facilitate attention to the upcoming target. Rather, through repeated exposure, infants would be expected to learn an association between the content cue and the location of the peripheral target, and then use that association to purposefully guide eye movements to the upcoming target location. In order to draw attention to a central cue and ensure the learning of the association between the cue and contingent peripheral target location, the central cue stimulus is usually manipulated to be attractive. Typically, the stimuli are made to be highly salient (e.g., high contrast, colors, motion and auditory components have all been used to enhance cue salience). An issue that has not previously been addressed is the degree to which the salience of the central stimulus influences the infant's performance on the stimulus-to-response task; a reasonable hypothesis might be that endogenous mechanisms in young infants might need to be scaffolded by inducing attention through the use of such salient targets.

Implications of the Gaze Shifting Literature

Of relevance to this issue are studies on gaze shifting in infants, which is rarely considered in the context of endogenous attention. In line with the stimulus-to-response task, gaze-shifting studies provide some evidence that infants as young as 4 months of age can use the content of the central stimulus to facilitate saccades to a particular location (Hood, Willen, & Driver, 1998; Farroni, Johnson, Brockbank, & Simon, 2000; Farroni, Mansfield, Lai, & Johnson, 2003; Farroni, Massaccesi, Pividori, & Johnson, 2004; Mansfield, Farroni, & Johnson, 2003).

The gaze-shifting methodology is similar to the stimulus-to-response task. For example, Hood et al. (1998) presented infants with a picture of a face in the center visual field for 1000 ms where the eyes appeared to be blinking. After the 1000 ms, the eyes shifted either toward the left or right indicating the location of the upcoming probe or target. Then the face was removed and the target was presented either to the left or right of the center stimulus. Within this paradigm two conditions are presented: congruent and incongruent. In the "congruent" condition, the gaze shift is directed at the location of the impeding target location. In the "incongruent" condition, the gaze shift is in the opposite location of the upcoming target location. The results indicate that infants 2½ to 7 months of age are faster at orienting to the congruent condition versus the incongruent condition, thus demonstrating that infants are able to reallocate their attention based on stimulus gaze. It is thought that infants use the content of the central stimulus to direct their attention to the location of the upcoming target. In the incongruent condition the longer response latencies are thought to reflect the need to redirect attention from the cued location to the actual target location.

The ability of infants as young as 2½ to 7 months of age to use the content of the central stimulus is highly relevant to an early account of endogenous attention. One could argue that if infants are able to use gaze to orient attention, then they should also be able to produce the same result with a variety of central stimuli (i.e., dynamic, multi-colored and auditory), thus replicating Johnson et al. (1991). However, several studies examining the effect of the stimulus content have not observed such results (Farroni et al., 2000; Farroni et al., 2004; Hood et al., 1998). For example, Farroni et al. (2003) found infants' facilitation of eye movements based on stimulus gaze occurs under the condition of three specific stimulus conditions: the use of a motion cue, the use of face stimuli, and the use of direct gaze to attract infants' attention.

The gaze shifting literature brings up two relevant points. First, the implications of these results are as follows: if infants cannot facilitate attention in absence of a face stimulus, it is likely that this ability is not a generalizable phenomenon, but is limited to a specific/modular type of stimulus entrainment or elicitation. Such logic can also be applied to the use of a motion and direct gaze cues. Second, the manipulation a central cue's content can obscure results on the stimulus-to-response task. More specifically, the salience of the central cue stimulus may play a significant role in infants' ability to perform the stimulus-to-response task independent of endogenous attention. In addition to examining infants' ability to perform the stimulus-to-response task, the current study attempts to examine the role, if any, played by the salience of the cue stimulus.

The Role of the Central Cue Stimulus Salience

It is an implied assumption that the location (i.e., spatial vs. central cue) and content of the central cue affects responding, but the salience of the central cue stimulus is often discounted or ignored. With adult subjects, the cue stimulus is typically simple. For example, the cue could be an arrow pointing in the direction of the upcoming peripheral target location. In this case, the aforementioned assumption holds. However, the practice of making the cue highly salient to attract infants' attention may void this assumption. Although it is presumed that the salience of the cue does not affect performance on the stimulus-to-response task, it is possible that the salience of the central cue might influence responding.

Courage, Reynolds, and Richards (2006) showed that infants respond differentially to dynamic vs. static versions of the same stimuli; more specifically, dynamic stimuli proved to be more engaging than the static stimuli (see also Shaddy & Colombo, 2004). The addition of motion increases the stimulus salience; thus, it is not surprising that infants find these stimuli more interesting than their static counterparts. In accordance, the manipulations performed on the cue stimulus in the stimulus-to-response task could be triggered by exogenous attention, and as such, should be examined. In other words, if infants' performance on this task is a result of the attention getting properties of the central cue stimulus, then their performance on this task would be exogenous driven rather than endogenously driven. If this is the case, operationally defining exogenous and endogenous responses for infants through the use of spatial and content cues may be erroneous. To address the issue of whether the salience of the central cue stimulus influences performance, cue salience will be manipulated in the present study.

Rationale for the Current Study

The purpose of the current study is to try and address two questions.

1. Are 4- and 9-month-old infants able to use the content of a cue stimulus to guide eye movements? Some research indicates that infants as young as 4 months of age are able to use the content of the cue stimulus to facilitate eye movements (Clohessy, 1993; Hood et al., 1998; Johnson et al., 1991). While other research indicates that the facilitation of eye movement can be attributed to spatial and temporal characteristics of the experiment, rather than infants' ability to use the content of the cue stimulus to facilitate eye movements (Colombo et al., 1990; Reznick et al., 2000). The resolution of these differences has direct implications for the study of the developmental onset of endogenous attention. Thus, the current study attempts to resolve this discrepancy through the replication and extension of the stimulus-to-response task with 4- and 9-month-olds. The choice of these two ages is based on theories that posits that volitional attention should be present in both (Johnson, 1991), or only the older (Colombo & Cheatham, 2006) of the age groups.

Infants were presented with a learning phase and a test phase. During the learning phase, infants were introduced to the contingent relationship between the central cue stimulus and the location of the upcoming peripheral target, in accordance with Johnson et al.'s (1991) study. The test phase was identical to the learning phase on 75% of the trials, the other 25% of the trials were "invalid," in that peripheral target appeared at the opposite location as it did during the learning phase. In Johnson et al.'s (1991) study, contingent learning was tested through the use of bi-lateral presentation of the peripheral target. However, Johnson's et al. (1991) "weak effect" of contingency learning, coupled with Clohessy's (1993) lack of contingent side preference, prompted the use of invalid trials as a measure of contingent learning.

2. Does the salience of the cue stimulus play a role in the ability to facilitate eye movements? The salience of the central cue stimulus was manipulated to explore the possibility that, at either age, the exogenous recruitment of attention might in some what scaffold or induce improved performance on the stimulus-to-response task. That is, might endogenous processes be influenced or triggered by exogenous manipulations?

Findings suggesting this outcome would provide some support for the notion that endogenous processes build on exogenous ones, and that the distinction between the two in development might, in fact, be more blurred than previously suggested in the extant literature.

Dependent Measures. Latencies and the direction of responses (i.e., correctly looking to the peripheral target or looking to the location opposite of where the peripheral target appeared) were used as dependent measures. Comparisons of latencies and direction of response across trials (as in Johnson et al., 1991) were performed. If infants are able to learn the contingent relationship between the cue and target, and use this information to guide eye movements, one would expect to see facilitation or an increase in anticipatory looks to the peripheral target location. Furthermore, performance during invalid trials was also examined. If infants are using the contingent relationship to facilitate eye movements, responses in the invalid condition should be contingent based and not target based. In other words, infants should look in the direction opposite to the appearance of the peripheral target.

Method

Participants

One hundred twenty five (62 male and 63 female) healthy, full-term infants were recruited by mail and telephone from the Kansas City metropolitan area. This population is predominantly upper-middle class socioeconomic status and the sample had the following ethnic composition: Caucasian (83%), Asian (6%), Hispanic (5%), American Indian (2%), African American (2%), and other (2%) participants. Participants were tested at either 4 months (*M* = 127.1 days, *SD* = 7.6) or 9 months (*M* = 273.8 days, *SD* = 10.1) of age. Of these 125 infants, 45 infants were excluded for the following reasons: prematurity (i.e., infants born before 37 weeks gestation, *n* = 8), fussiness or sleepiness (*n* = 22), parental interference (*n* = 3), equipment failure (*n* = 2) or other various reasons (e.g., inadequate number of good trials completed, persistent inattention, playing with the booster seat, or pacifier use; *n* = 10).

The 80 remaining infants contributed to subsequent analyses. Demographic characteristics for the remaining sample, split by the respective age groups, are presented in Tables 1 and 2. There were no significant differences on the demographic characteristic between the 4 and 9-month-old infants.

Stimuli

During the procedure, infants were presented with a stimulus at midline, which served as a cue for the upcoming peripheral target location. The cue stimulus subtended approximately 5º of visual angle. There were a total of four possible cue stimuli, two per salience condition.

For the *low salience* condition, the cue stimuli were high contrast multi-chromatic and static. To ensure infants' ability to discriminate between these two stimuli, the shape and color scheme was varied (e.g., square pattern containing a red, black, and white color scheme vs. a circular pattern containing a yellow, blue, and green color scheme; see Figure 1).

For the *high salience* condition, the cue stimuli consisted of the same two high contrast multi-chromatic stimuli as in the low salience condition. To assure the

Table 1

Demographic Characteristics for 4-month-olds

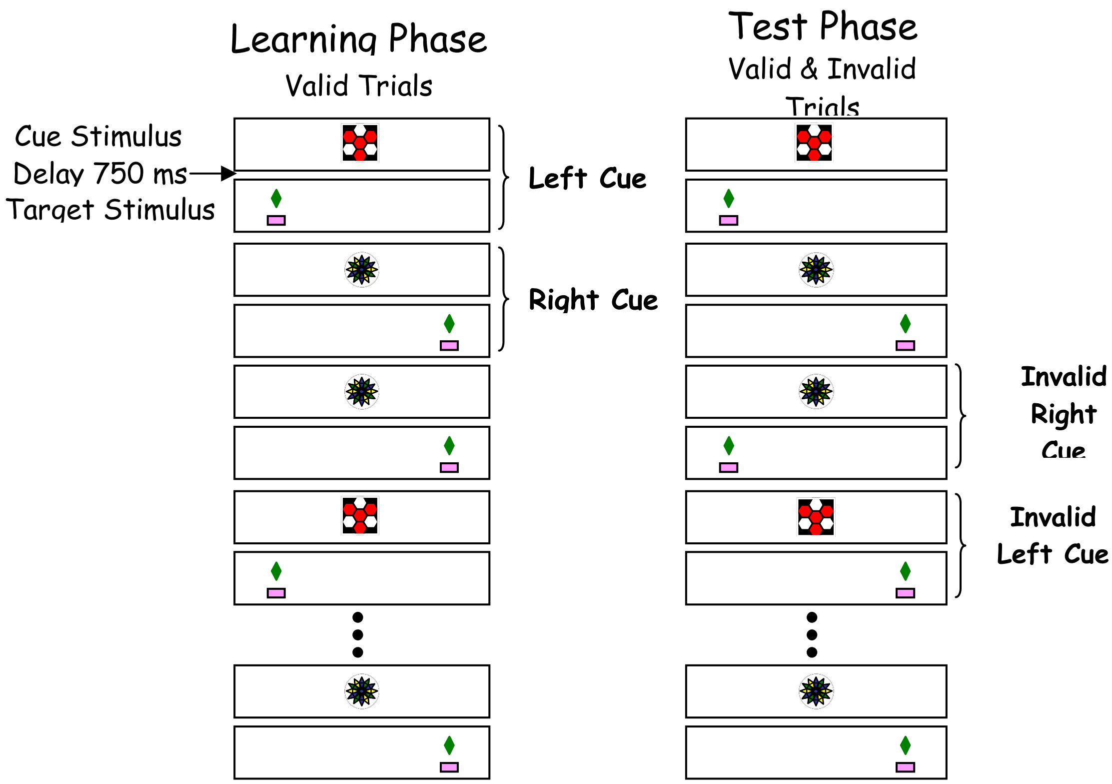
	4-month-olds			
Infant Characteristics	*M*	*SD*	*Min*	*Max*
Age at Testing (days)	127.5	6.7	112.0	141.0
Conceptual Age (days)	123.9	8.3	107.0	140.0
Birth weight (grams)	124.0	12.9	101.0	153.0
Family Characteristics	*M*	*SD*	*Min*	*Max*
Maternal Age (years)	30.0	4.7	22.0	41.0
Maternal Education (years)	16.3	1.8	12.0	20.0
Paternal Age (years)	32.1	5.4	24.0	46.0
Paternal Education (years)	16.3	1.9	12.0	20.0
Number of Siblings	0.5	0.8	0.0	3.0

Table 2

Demographic Characteristics for 9-month-olds

	9-month-olds			
Infant Characteristics	*M*	*SD*	*Min*	*Max*
Age at Testing (days)	274.7	9.8	247.0	307.0
Conceptual Age (days)	270.9	11.5	242.0	300.0
Birth weight (grams)	125.39	16.2	64.0	152.0
Family Characteristics	*M*	*SD*	*Min*	*Max*
Maternal Age (years)	31.9	4.6	22.0	43.0
Maternal Education (years)	16.6	1.4	14.0	20.0
Paternal Age (years)	33.3	4.8	24.0	43.0
Paternal Education (years)	16.2	1.7	12.0	20.0
Number of Siblings	0.8	1.1	0.0	4.0

Figure 1. *Presentation of Learning and Test Phase*



prominence of the high salience cue stimuli a motion and an auditory component was included. The type of motion and sound varied among the center stimuli (e.g., a square pattern that rotated with an accompanying regular beep vs. a circular pattern which expanded and contracted with an accompanying irregular beep). A pilot study was conducted determine if infants could discriminate between the cue stimulus pairs. Thirty-seven infants ages 4 and 9 months (M = 123.8 days, SD = 8.1; M = 276.6 days, SD = 10.6 respectively) were assigned to either a high or low salience condition. Infants' were then habituated to one of the cue stimulus pair using an infant-control sequence, with a criterion of two consecutive looks at a 50% decrement from the previous longest look. Following habituation, infants were tested for novelty preference using the length of looking to the stimuli as the dependent variable. Length of looking was then entered into an Age (2) x Salience (2) x Familiarity (2) three factor mixed design Analysis of Variance (ANOVA). All main effects and interactions were significant ($p < .05$), indicating that both 4- and 9-month-olds were able to distinguish between the high and low salience cue stimulus pairs.

The peripheral target stimulus comprised of a flashing pink diamond above a green rectangle, analogous to the peripheral target employed in Johnson et al. (1991). The peripheral target was identical at both locations and was sized at 3º visual angle and was located at 34º to the left or right of cue stimulus (see Figure 2).

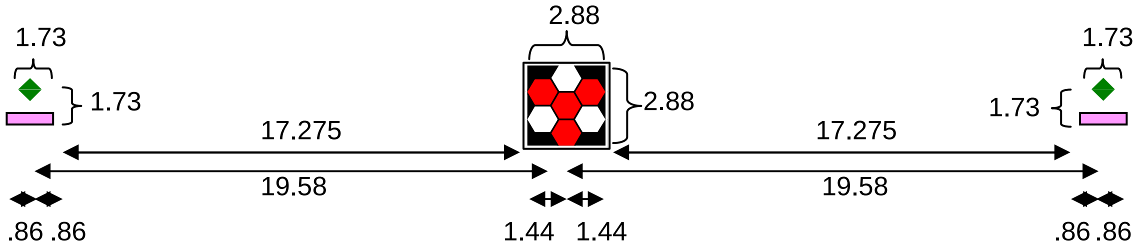
Apparatus

All infants were tested in a 2 m × 2 m room with black walls and ceiling. Infants were placed in an adjustable booster seat approximately 1 m away from a flat-screen Dell

Figure 2. *Stimulus-to-Response Set Up Compared to Other Studies*

Current Study

Center Stimulus: 5°
Peripheral Stimulus: 3°
Peripheral Distance: 34°



Anti-Saccade

<u>Johnson et al. (1994)</u>
Center Stim: 5°
Peripheral Stim: 3°
Peripheral Distance: 29°

<u>Johnson (1995)</u>
Center Stim :5 °
Peripheral Stim: 3°
Peripheral Distance: 29°

Visual Expectation

<u>Haith et al. (1988)</u>
L/R Stim: 4.5°
Distance from center: 5.7°

Learnin

<u>Johnson et al. (1991)</u>
Center Stim: 5°
Peripheral Stim: 3°
Peripheral Distance: 34°

<u>De Schonen & Bry (1987)</u>
Center Stim: (R/L): 9°6 x 6°3
Peripheral Stim: ?
Peripheral Distance: ?

W3000 LCD television monitor. Stimuli were presented on the .18 m × .538 m monitor via a computer.

A JVC digital video camcorder was centered above the screen, and an observer located in the adjacent room monitored the infant on closed-circuit television. The observer coded looking behavior on-line using a key press connected to a computer that kept track of the length of looking and direction of infant gaze, as well as controlled the stimuli presentation.

Design

The experiment was a mixed-factorial design including between-subject factors of Age (2: 4- vs. 9-month–olds) and Salience (2: low vs. high) and within-subject factors of Phase (2: test phase vs. learning phase) and Trials (20). In the *low salience* condition, the cue stimulus presented at midline was either a static square or static circular pattern with no auditory component. In the *high salience* condition, the cue stimulus presented at midline was either a dynamic square or dynamic circular pattern with an auditory component.

The presentation of the cue stimulus was paired with the peripheral target at a specific spatial location. For example, the presentation of the square pattern was paired with a peripheral target location that always occurs to the left of the cue stimulus, while the circular pattern was paired with a peripheral target location that always occurred to the right of the cue stimulus (see Figure 1).

The trials were administered in two sections of 20 trials each. The first 20 trials served as the *learning phase*. The learning phase allowed the infants to learn the contingent relationship between the cue stimulus and the upcoming peripheral target location. During the learning phase, all trials were valid; that is, on all trials, the square pattern was always paired with a left peripheral target location and the circular pattern was always paired with a right peripheral target location. The second section served as the *test phase,* where only 75% of the trials were valid (i.e., with the target appearance location consistent with the pairing used during the learning phase). The other 25% of the trials were invalid, where the presentation of the cue stimulus and contingent peripheral target location were reversed (i.e., peripheral target appeared at the opposite location as it did during the learning phase, see Figure 1). The presentation of the cue stimulus and peripheral target location was counter-balanced across and between phases. During the test phase, the presentation of the valid and invalid trials were randomized and were presented in a blind fashion (i.e., the experimenter was unaware of the trial validity).

Procedure

Upon arrival, caregivers were informed of the experiment's purpose and informed consent was administered (see Appendix A). The participant was then placed in an adjustable booster seat in the testing room. The seat was adjusted to accommodate for individual differences in height among the infants. A person (usually the caregiver) remained in the room with the infant at all times. Once the infant was in front of the presentation screen, and was in a content state, the lights were dimmed to off and the experiment began.

At the beginning of the experiment, infants were exposed to the learning phase followed by the test phase. In the learning phase, infants were presented with a cue stimulus. Once the infant had accumulated 2 s of looking at the cue stimulus, the cue was removed. The presentation of the peripheral target occurred 750 ms after the removal of the cue stimulus. When the infant looked to the peripheral target, the experimenter pressed a button indicating that a gaze/ocular shift had occurred. The infant was allowed to look to the peripheral target until he/she looked away, or until 5 s had passed. Then the peripheral target was removed and the next trial presentation occurred. If the infant did not look to the peripheral target within 5 s of the removal the cue stimulus the trial was deemed unusable; however, the trial was continued until the infant looked to the peripheral target. The trial was continued to ensure that infant had been exposed the contingent relationship; to learn the contingent relationship infants had to be exposed to both left and right target presentations. Terminating the trial after 5 s, however, could result in infants' looking only one of the two peripheral locations or never seeing either of the peripheral targets. Thus, infants were given sufficient time to look to the peripheral target. If an infant did not look to the target within 5 s of the removal of the cue stimulus the latency for that trial was removed from the analyses. Twenty trials were presented during the learning phase.

The test phase used the same stimuli pairs as those used in the learning phase. The only variation came in terms of the degree to which the cue was "valid," or predictive, of the location of the subsequent peripheral target. In the learning phase, the cue was 100% valid; in the test phase, validity was dropped to 75% (i.e., 25%

of the trials were invalid). After infants completed 20 trials, the test phase session was concluded.

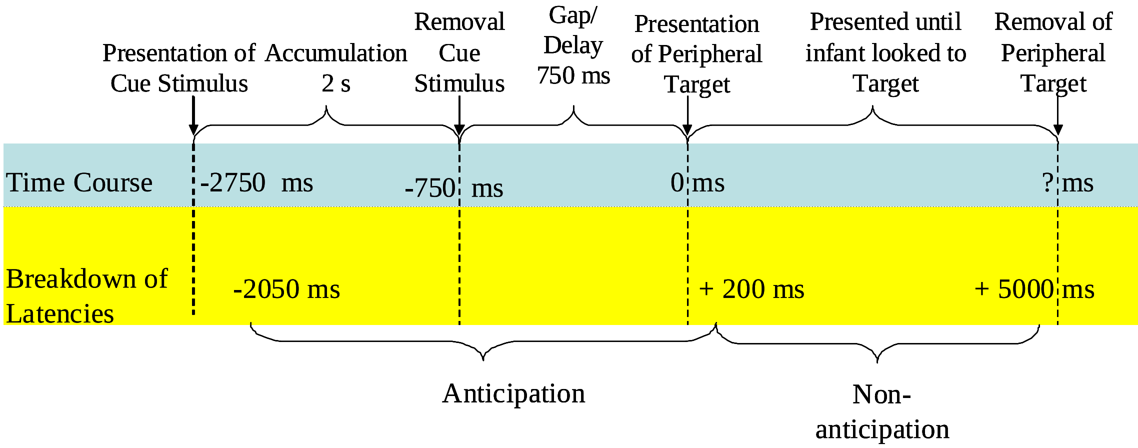
If the infant cried or refused to look at the stimuli during a particular trial, that trial was terminated and not used in the analysis. The session was continued if the infant returned to a calm state, and subsequent non-fussy trials were kept for analysis. If fussiness continued and the infant did not return to a content state, the session was terminated. Upon conclusion of the session, parents were asked to complete a health questionnaire (see Appendix B). Finally, the experimenter offered to answer any additional questions the parent might have.

Data Reduction

Coding and Calculation of Latencies and Responses. Infants' performance on any given trial was examined in terms latency and the direction of response provide. For all trials, latencies were calculated on a frame-by-frame (33 ms resolution) basis using motion pro software that allows for frame-by-frame control of the video recording, and which provides the frame count. The calculation of latency started with the presentation of the peripheral target and continued until the infant made an eye movement or gaze toward a peripheral target location. It should be noted that, in instances where the infant look to the peripheral target location prior to its presentation (i.e., anticipation), latencies were recorded as negative (see Figure 3).

In addition to the measurement of latency, a response variable was created to indicate the direction of infant gaze. Initially, the response variable was classified into one of four categories: *correct, incorrect, null,* and *missing*. The *correct* category

Figure 3. *Temporal Breakdown of Response*



consisted of trials where the infants looked to the peripheral target. The *incorrect* category consisted of trials where the infants looked to the opposite location of the presentation of the target. Trials where the infant did not look to either of the target locations or eventually looked to a target location after looking to other locations (e.g., to mom, camera, etc.) were categorized as *null responses*. Trials that were not presented or were timed out were labeled *missing*.

During the test phase, responses for valid and invalid trials were analyzed collectively. By definition, a correct response should indicate contingent based responses. During valid trials, a *contingent-based* response would correspond to a look to the peripheral target signaled by the content of the central cue. Violation of the contingent relationship during invalid trials would result in a look to the peripheral target that we termed *target-based* responding. Thus, an adjustment in the classification of responses during invalid trials is necessary to ensure that a correct response corresponds to a contingent based response. If infants were making contingent-based responses during invalid trials they should look to the location to where the target should have appeared (i.e., the contingent location) rather than looking to the location where the target was actually presented. Accordingly, during invalid trials a look to the opposite location of the peripheral target (i.e., to where the target should have appeared) was classified as a *correct* response, while a look to the peripheral target was classified as an *incorrect response*.

All correct and incorrect responses yielded usable information, and thus were used to examine infants' abilities to learn and use a contingent relationship. It is worth noting that, although null responses were not expressly examined, these responses were used in the denominator to create a proportion of response. The sessions were later coded for reliability, and the reliability of coding latencies from the video clips was highly consistent, with interobserver records correlating at $r = +.99$.

For the purpose of the current experiment, we were particularly interested in infants' ability to anticipate the peripheral target, thus, the remaining usable responses were further decomposed in terms of *anticipatory* responses and *non-anticipatory* responses. On trials where infants made a response prior to the presentation of the peripheral target (i.e., latencies that greater than -2050 ms and less than 200 ms; see Figure 3), response were categorized as *anticipatory*. This anticipation window was created by taking the temporal range from the presentation of the central stimulus (-2750 ms) to the presentation of the peripheral target (0 ms), and shifting it by 200 ms. The value of 200 ms represents response time, and is the suggested cutoff for anticipations by Haith et al. (1998) and Clohessy et al. (2001). Lastly, an additional 500 ms was subtracted from the onset of the temporal window to ensure that infants observed the central stimulus before looking to the target location. Trials where the infants gazed the peripheral target after its presentation responses were labeled *non-anticipatory*, specifically latencies that are greater than 200 ms and less than 5,000 ms. Thus, usable latencies were classified into the following categories: correct anticipation, incorrect anticipation, correct non-anticipation and incorrect non-anticipation, however, for the purpose of the current study only anticipatory responses will be discussed. Non-anticipatory responses were excluded from the current study to avoid the possibility that infants making non-anticipatory responses are responding to the appearance of the peripheral target (i.e., exogenous driven eye movements).

Furthermore, these categories are mutually exclusive and consequently a correct anticipation on a given trial will result in a missing data point for incorrect anticipation and non-anticipation categories on that trial. To adjust for this missing data and to maximize data used, two procedures were employed. First, mixed models were used with this data set to allow for the use of all the data points. Second, latencies for each infant were averaged from the 20 trials within the learning and test phases to create 5 blocks of 4 consecutive trials (i.e., an average latency was obtained for trials 1-4, 5-8, 9-12, 13-16, and 17-20).

Results

Analysis Plan and Predictions

Latencies and direction of responses were examined to determine if infants were able to use a contingent relationship between the content of the cue stimulus and the peripheral target location to facilitate eye movement to the location of the impending peripheral target. Of most interest was the *correct anticipation* category; if infants were able to use the contingent relationship between the content of the cue stimulus and the location of the peripheral target, then we would expect that, as learning progressed,

(a) correct anticipatory responses would increase across the learning phase, and

(b) latencies for correct anticipations would decrease across the learning phase

We further expected that, if infants were learning the contingency, the introduction of invalid trials during the test phase would disrupt this pattern. The test phase featured the introduction of the invalid trials, which were intended to serve as "catch trials" to determine whether infants had learned the original contingency. However, the inclusion of invalid trials violates the contingent relationship between the cue stimulus and the peripheral target. If infants recognized the violation of the contingent relationship, then performance during the testing phase should be interrupted.

One problem with examining only correct anticipations when infants are producing other types of responses is that this measure *per se* provides no appropriate controls or comparison against which performance might be measured. Therefore, we included incorrect anticipations (i.e., anticipatory responses to the "wrong" location, as signified by the central cue) as a means of providing that control. As the most straightforward indicant of learning, we would expect simply that

(a) anticipations to the correct side would be more frequent than anticipations to the opposite or incorrect side, and

(b) the analysis of incorrect anticipations would produce inverse results from the results obtained with correct anticipations (i.e., decrease across the learning phase as infants learn the contingent relationship), although it was unclear as to whether specific changes in latencies might be seen for such incorrect responses.

Finally, the type of response occurring during invalid trials was also examined. If infants were using the contingent relationship to guide eye movements, then responses during invalid trials should be contingent-based. In other words, during invalid trials infants are expected to look to the location to where the target *should* have appeared rather than looking to the location where the target was actually presented.

Performance Across the Phases.

Proportion of Responses. To examine the direction of responses produced, a proportion was calculated. For example, the proportion of correct anticipatory responses was computed by taking the total number of correct anticipation responses in a given block and dividing the total number of all responses (i.e., correct, incorrect, and null) provided in that block. It is important to note that, because of the incorporation of null responses into the denominator of the proportions, comparisons of correct and incorrect these proportions were not inversely isomorphic; that is, the proportions of correct and incorrect anticipations did not sum to 1.00. As such, they were not strictly collinear and could be included as a within-subject factor.

A hierarchical linear model (HLM) was run on the proportion of all anticipations using the predictors of Age (2) × Salience (2) × Direction (2) × Phase (2) × Block (5). The HLM produced a significant main effect of Age, $F(1, 1421.36) = 16.32$, $p < .001$, such that 4-month-old infants (M = .171) produced significantly more anticipatory responses (i.e., both correct and incorrect) relative to 9-month-old infants (M = .130). There was also a significant main effect of Salience, $F(1, 1421.36) = 8.37$, $p < .01$, indicating that infants in the high salience condition (M = .165) produced significantly more anticipations overall (again, both correct and incorrect responses) relative to infants in the low salience condition (M = .136).

These results were qualified by a significant Age × Phase interaction, $F(1, 1421.36) = 4.67$, $p < .05$: 4-month old infants showed a decrease in anticipatory responses from the learning phase to the test phase, while the 9-month-old infants responses showed an increased pattern of anticipatory responses (see Figure 4). Because this interaction collapses across correct and incorrect anticipations, little can be said about learning.

These results were further qualified to some degree by a marginal Age × Salience × Direction interaction, $F(1, 1421.36) = 3.73$, $p = .054$. For the high salience condition, 4-month-old infants produced significantly ($p<.05$) more correct anticipations than incorrect anticipations, while 9-month-old infants produced only slightly more correct anticipations than incorrect anticipations (*ns*). When examining the low salience condition, no significant differences were obtained between correct and incorrect anticipations for either age (see figure 5). The significant increase in correct anticipations in the high salience condition might be taken to indicate that 4-month-olds learned the contingency; however, this does not appear to be the case. If infants were able to use the learning contingent relationship to guide eye movement we would expect to see an increase in the number of correct responses across the learning phase, which would indicate that after learning the contingent relationship infants were then able to use the relationship to facilitate eye movements to the peripheral target. Furthermore, the introduction of invalid trials should disrupt performance resulting in a decrease in correct anticipations demonstrating that infants recognized the violation of the contingent relationship. Yet, there was no change in the production of correct anticipations within or across the phases.

Figure 4. *Proportion of Anticipation by Age and Phase*

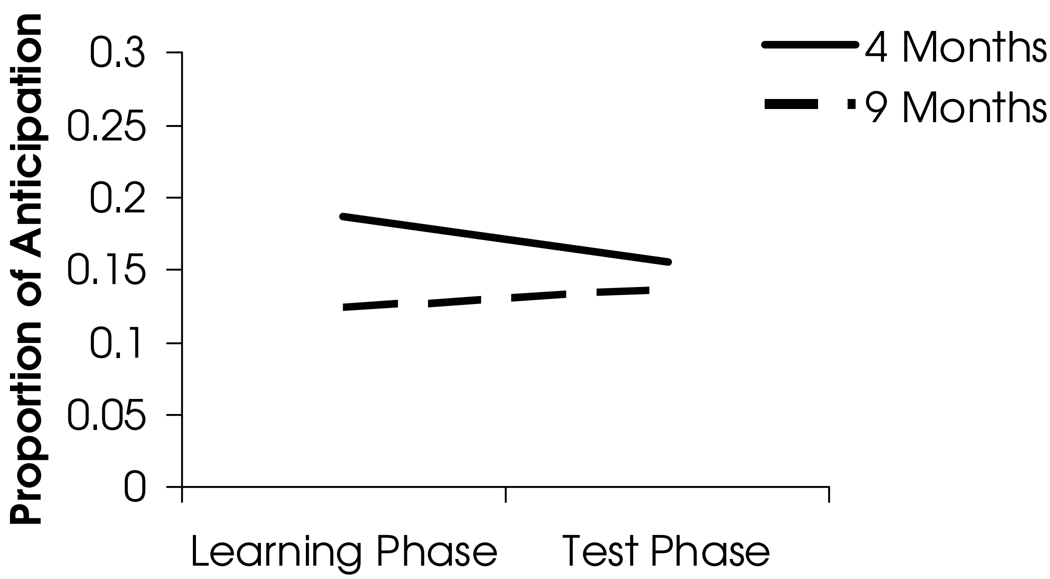
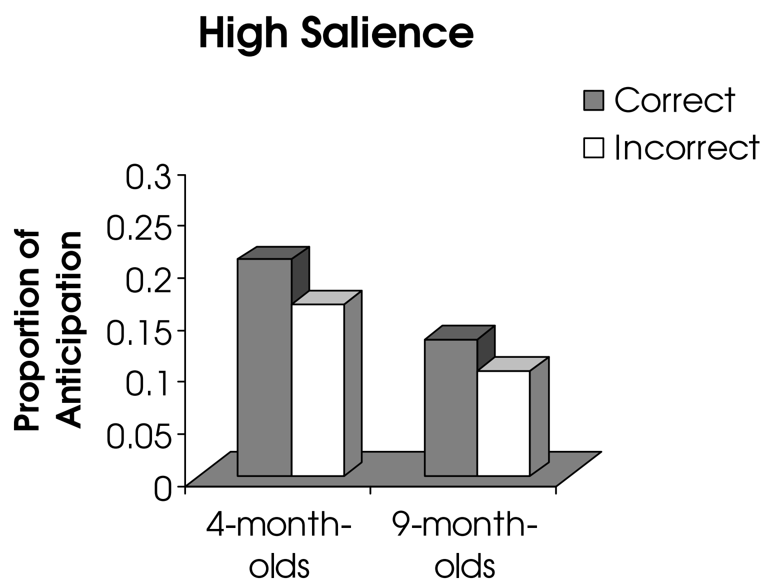
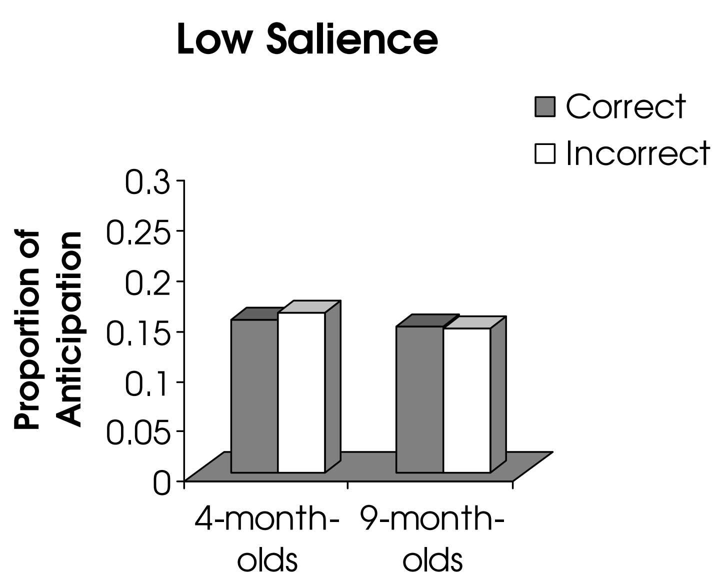


Figure 5. *Proportion of Anticipation by Direction, Salience and Age*



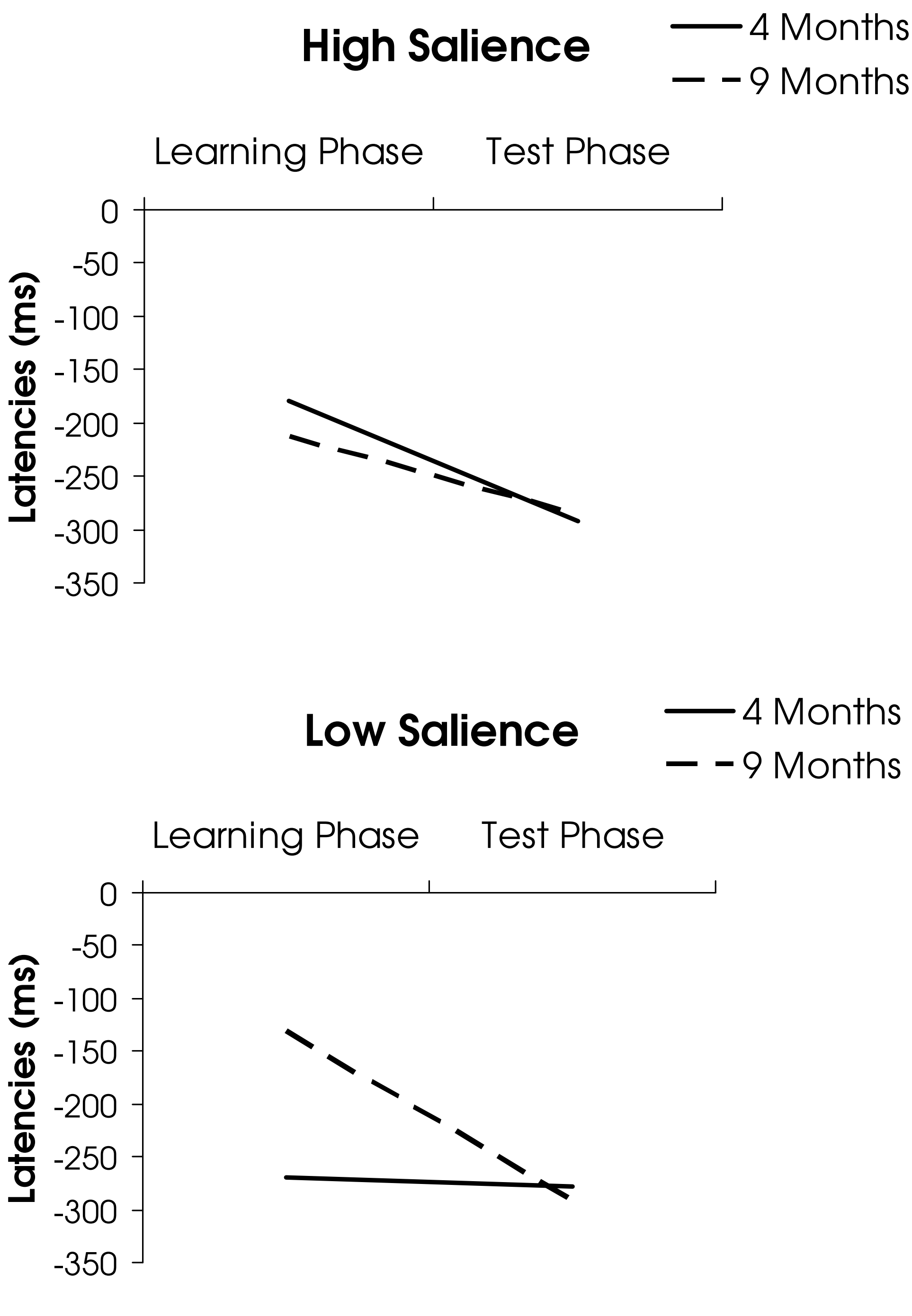


The marginal effect of 4-month-olds in the high salience condition producing more correct anticipation than incorrect anticipation alone does not provide conclusive support of infants' use of the contingent relationship. Thus, the current analysis provides no definitive evidence that either group was capable of learning the contingency. Of some importance was the finding that cue stimulus salience affected infants' responses, such that, infants produced more responses overall to the high salience condition than low salience condition.

Latencies. A mixed-model analysis was run on the mean latencies for all anticipations, using the predictors of Age × Salience × Direction × Phase × Block. There was a significant main effect of Phase $F(1, 502.66) = 13.055$, $p < .001$, indicating that infants produced significantly shorter latencies during the test phase (M = -287.199) than learning phase (M = -198.196). There was also a significant main effect of Block, $F(1, 199.32) = 2.96$, $p < .05$, indicating that infants latencies decreased across the 5 blocks. Finally, there was a significant main effect of Direction, $F(1, 502.66) = 10.754$, $p < .01$ indicating that latencies were significantly shorter when infants produced incorrect anticipations (M = -283.087) than when they produced correct anticipations (M = -202.308).

These results were further qualified to some degree by two interactions. First, a marginal Age × Salience × Phase interaction, $F(1, 502.66) = 3.745$, $p = .054$ emerged. Nine-month-olds showed shorter latencies in the test phase than the learning phase in both salience conditions; 4-month-olds showed this pattern for the high salience condition, but not for the low salience condition (see Figure 6). Again, this does not

Figure 6. *Anticipation Latencies by Salience, Phase and Age*

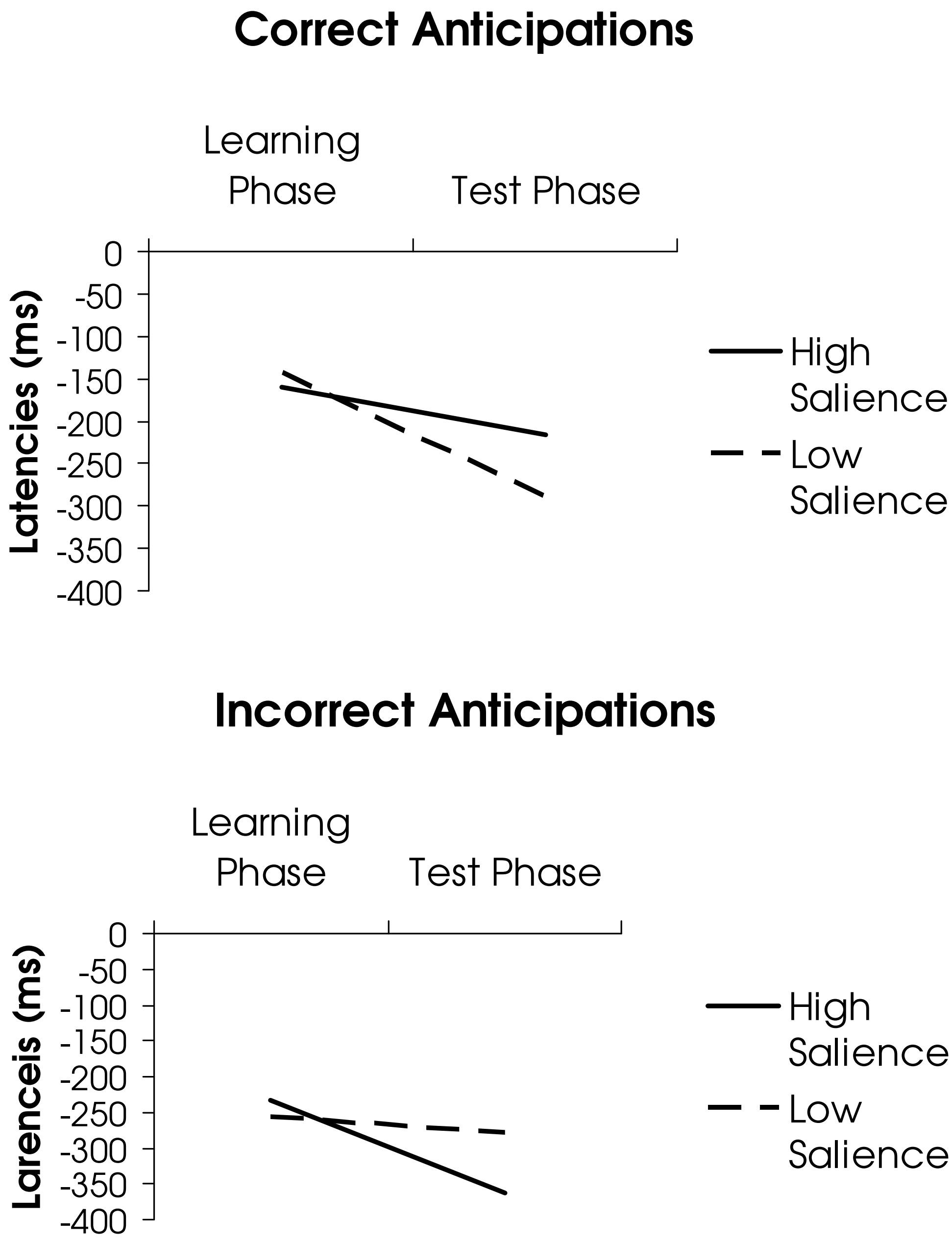


specifically reflect learning as these results are collapsed across correct and incorrect anticipations. However, it is interesting that once again 9-month-old infants provided similar performance for the low and high salience conditions, while 4-month-old infants' performance between the low and high salience conditions differed.

Second, there was a significant Salience × Direction × Phase interaction, $F(1, 502.66) = 4.157$, $p < .05$. Latencies were shorter in the test phase than in the learning phase, except for incorrect anticipations in the low-salience condition; there was no change in across phases in that condition (see Figure 7). If infants were responding based on the contingent relationship, it follows that we would expect latencies to decrease across the learning and test phases for correct anticipations; however, latencies significantly decreased for incorrect responses in the high salience condition. The fact that infants in the high salience condition produce a similar decrease in latencies across the phases for both correct and incorrect responses implies that infants in the high salience condition are not facilitating eye movements based on the content of the central stimulus. Rather, infants in high salience condition are responding faster overall.

Summary. Several interesting findings emerged from these analyses. Four-month-olds generated more anticipatory responses overall than 9-month-olds. Infants in the high salience condition also produced more anticipatory responses than infants in the low salience condition. When producing incorrect responses latencies were significantly shorter. Finally, latencies tended to decrease across and within the learning and test phases. This decrease was observed for 9-month-olds in both the low and high salience conditions as well as for 4-month-olds in the high salience condition.

Figure 7. *Anticipation Latencies by Salience, Phase and Direction*



One critical finding, however, failed to emerge. Performance did not fundamentally vary as a function of the correct or incorrect nature of infants' responses. In other words, the changes observed in responses and latencies occurred for both correct *and* incorrect anticipation responses. If infants were responding based on the contingent relationship, correct and incorrect response should show differential patterns of change across session. However, responding increased across phases for both correct and incorrect anticipatory responses. Given this pattern of results, it is cannot be concluded that infants were responding based on the contingent relationship.

A particularly interesting finding that emerged was that salience affects performance in the stimulus-to-response task. More specifically, the high salience condition was associated with increased responses and a decrease in latencies across the learning and test phases. These results are further differentiated by age; 4-month-olds' performance was affected by the salience of the cue stimulus, while 9-month-olds' was not. For 4-month-olds the manipulations of salience affects both dependent variables (i.e., the direction of responses and latencies). Interestingly, data from the high salience condition give the impression that 4-month-olds were successful in the stimulus-to-response task. We reiterate, however, that (based on the correct-incorrect comparisons) we find it unlikely that 4-month-olds are using the contingent relationship to facilitate eye movements. For young infants, the high salience condition appears to obscure the data. What is mostly like happening is that attention getting properties of the high salience cues is prompting 4-month-olds to engage, but they are responding in a random or haphazardly fashion.

Performance During Invalid Trials

Invalid trials were included to serve as an additional measure of infants' ability to perform the stimulus-to-response task. Performance during invalid trials was examined to determine if behavior during these trials provide any support for contingent based behavior. A mixed-model analysis run on the responses provided during invalid trials using the predictors of Age (2) × Salience (2) × Direction (2) yielded no significant effects, indicating that during invalid trials infants were not basing their responses based on any prior predictive contingent association.

Summary. The analysis of invalid trials provides additional support for the conclusion that infants were not responding based on the contingent relationship. If infants had learned the relationship between the central cue and peripheral target and were using the relationship to facilitate eye movements, then infants should be making contingency-based responses. However, during invalid trials infants' anticipatory responses were not attributable to the learned association.

Discussion

The purpose of the current study was to examine the possibility that young infants possess internally-driven behavior, as measured by the stimulus-to-response task. To achieve this goal, two questions were addressed.

Are 4- and 9-month-old infants able to use the content of a cue stimulus to guide eye movements?

In line with Johnson et al.'s (1991) study, both 4- and 9-month-old infants showed a decrease in latencies across the learning and test phase, but even though we were able to replicate the decrease in latencies across the learning and test phase obtained by Johnson et al. (1991), we were unable to attribute these changes to processes related to endogenous attention at 4 months of age. Two supplementary findings indicated that infants were not able to use the content of the cue stimulus to guide eye movements. These two findings are discussed in detail below.

Correct Anticipations vs. Incorrect Anticipations. Initial analyses revealed that infants produced correct anticipations 16.4% of the time, but that the probability of incorrect anticipations was approximately the same (14.7%). The small percentage of correct anticipation coupled with an almost equal number of incorrect anticipations led to a critical examination of infants' behavior when they were not anticipating the correct target location.

The analyses of incorrect and correct anticipations indicated that the results for incorrect and correct anticipations are analogous. If infants had learned the contingent relationship and were making eye movements based on this relationship, the results obtained from the incorrect responses should be reverse of those obtained from correct anticipatory responses. This was not the case. Instead, infants provided correct and incorrect anticipation responses under similar circumstances, thus implying that infants are not responding based on the contingent relationship.

As an additional measure of learning, invalid trials were incorporated to determine if infants detected violation of the presumably-acquired contingent relationship. The analysis of invalid trials indicated that infants respond based on the appearance of the target and the contingent relationship equally. Again, if infants were using the contingent relationship to facilitate saccades, then they should be exhibiting contingent based responding. Furthermore, during the test phase, the introduction of the invalid trials should disrupt the progress made during the learning phase. However, there was no indication that infants noticed violations of the contingent relationship when making anticipatory responses during the test phase. Rather, it appeared that infants were responding in a random manner. Thus, the inclusion of incorrect anticipation in the analyses provided additional evidence to bolster the contention that infants were not using the content of the cue stimulus to guide eye movements.

Developmental Trends. Further indication that the stimulus-to-response task does not provide a measurement of internally driven behavior comes from the changes observed in developmental differences on this task, or more specifically lack there of. The stimulus-to-response task has been closely tied to prefrontal function (Quintana & Fuster, 1992; White & Wise, 1999), and as such can be used as a marker task for endogenous attention. In addition, other marker tasks of endogenous attention have shown a marked progression; thus, some kind of developmental progression on this task would be expected. If endogenous attention develops prior to 9 months of age, one would expect younger infants to be able to perform the task at some sort of baseline level followed by improvement with age. The current analysis, however, indicates that younger infants are more accurate and efficient at this task than older infants. Given these results, it is not surprising that Clohessy (1993) did not find an improvement in performance on stimulus-to-response task. Furthermore, Clohessy (1993) found that infants were producing a significant amount of correct anticipations across the learning and test phases, but these values did not change with age. The lack of developmental progression on the stimulus-to-response task brings into question whether the stimulus-to-response task is measuring internally driven behavior when used with infants. This result coupled with results obtained from the anticipation analyses leads to the conclusion that the current study stimulus-to-response task is not measuring internally driven behavior.

Does the salience of the cue stimulus affect infants' performance in the stimulus-to-response task?

The measurement of endogenous shifts of attention, within the adult literature, is done through the use of content cues. Traditionally, these cues are simple and do not trigger automatic or exogenous responses. Our second question asked if the practice of manipulating cue stimulus to attract infants' attention affects the performance on the stimulus-to-response task. The results indicate that the salience of the cue stimulus does influence infants' performance to the stimulus-to-response task. More specifically, the high salience condition is associated with more responding overall. Thus, it appears that the high salience cue stimuli are more engaging than the low salience cue stimuli thereby resulting in an increase in responding.

The salience effect can be further broken down by age, such that salience did not affect the direction of response provided by 9-month-olds, but it did affect 4-month-old responses. Four-month-olds in the high salience condition produced significantly more correct responses than in the low salience condition. Furthermore, latencies significantly decreased across the learning and test phase for 9-month-olds irrespective of salience condition. The observed decrease in latencies could reflect some sort of activation of attention, and may be due to infants forming an expectation of the appearance of a peripheral target. Although, infants are not anticipating the correct peripheral target location, they may be anticipating the appearance of the peripheral target. Although, this anticipation could reflect endogenous attention, further research is necessary to explore this possibility.

Regardless, it appears that manipulating salience can affect the outcome of the stimulus-to-response task for younger infants. One could argue that this effect of salience is necessary to keep infants engaged in the task and that it does not negate the results. In other words, once infants' attention is directed to the cue they can then process the cue and use the information to guide eye movements. However, the significant decrease in latencies observed for 4-month-olds in the high salience condition was obtained for both correct and incorrect anticipatory responding, and the lack of change in the production of correct anticipation in the high salience condition for 4-month-olds indicates that infants are responding based on a learned association. Thus, the high salience condition triggers 4-month-olds to respond in the stimulus-to-response task, but not based on the contingent relationship; rather they are more engaged and responding to the peripheral target locations, irrespective of the content of the central cue stimulus. Although this finding is unexpected, it is consistent with the notion that 4-month-olds are more exogenously-driven than 9-month-olds.

Critically, the finding also suggests that the practice of making the cue highly salient to attract infants' attention in the stimulus-to-response task may differentially affect young infants' performance in the task, resulting in an increase in the number of responses irrespective of contingent relationship. It seems that the overall elevation in responding is driven by the engaging properties of the central cue stimulus and not the contingent relationship. Thus, young infants' performance in the high salience condition appears to be exogenously driven rather than endogenously driven. Such a phenomenon would functionally provide a different base rate of responding in such paradigms, and might lead to the erroneous impression (if uncontrolled analyses were conducted) that 4-month-olds were capable of endogenous or volitional attention.

Summary and Concluding Remarks

The current study reproduced the results obtained by Johnson et al. (1991), but supplementary analyses showed that such data did not allow a tenable conclusion of endogenously driven behavior in either 4- or 9-month-olds. Although the initial results indicated that infants were able to perform the stimulus-to-response task, more controlled examination of the data indicated that infants were not responding based on the contingent relationship. Rather, it appears that infants, particularly young infants, are simply responding in a non-discriminatory fashion, and that increasing the salience of the central cue target resulted in an increase in such nondiscriminatory behavior in the younger infants. Given the current results, we cannot conclude that 4-month-old infant's exhibit internally driven behavior. While the prevalent theory of the development endogenous attention does not need to be recast to incorporate an earlier onset, it is the case that even older infants were not shown to be strictly capable of endogenous responding. There may be further constraints on the processing capacities at older ages; this is a topic worthy of future research.

The current study, however, does bring up two methodological points that are highly relevant to the study of infant attention. The purpose of the current study was to examine changes in latencies and responses when infants are making saccades toward the peripheral target (i.e., correct anticipations). However, early analysis indicated that infants are producing a small amount of correct anticipations and making a similar number of incorrect anticipations. In the current study the incorporation of incorrect responses in the analysis provided additional insight and prevented erroneous conclusions. One major supplementary finding is the importance of analyzing all measured responses. This point is especially relevant within the infant literature when subjects do not always behave as expected.

The second point worth noting has to do with the methodological changes made to the stimulus-to-response task. The custom of making the central stimulus highly salient to attract infants' attention affects performance on the stimulus-to-response task, and seems to also affect the underlying assumption of the stimulus-to-response task. In other words, in the process of changing the cue stimuli from a simple arrow to dynamic stimuli negates the operational definition of endogenous responses as measured by the stimulus-to-response task. Infants appeared to be responding to the attention getting properties of the central cue stimulus, and as such performance on this task is exogenous driven rather than endogenously driven. The methodological changes performed to ensure infants involvement can result in a change in what is being measured. It should always be noted that when procedures are modified they may no longer represent the same construct.

In conclusion, the data from the current experiment indicates that neither age group exhibited the ability to use the content of the central cue stimulus to facilitate eye movement to the upcoming peripheral target. We were unable to find evidence of endogenous attention using the stimulus-to-response task.

References

Adler, S.A., & Haith, M.M. (2003). The nature of infants' visual expectations for event content. *Infancy, 4(3),* 389-421.

Aron, A.R., Sahakian, B.J., & Robbins, T.W. (2003). Distractibility during selection-for-action: differential deficits in Huntington's disease and following frontal lobe damage. *Neuropsychologia, 41*, 1137-1147.

Bell, M.A. (1998). Frontal lobe function during infancy: implications for the development of cognition and attention. In J.E. Richards (Ed.), *Cognitive Neuroscience of Attention* (pp. 287-316). Mahwah, NJ: Lawrence Erlbaum Associates.

Bell, M.A., & Fox, N.A. (1992). The relation between frontal brain electrical activity and cognitive development during infancy. *Child Development*, *63,* 1142-1163.

Bell, M.A., & Fox, N.A. (1994). Brain development over the first year of life: Relations between electroencephalographic frequency & coherence and cognitive & affective behaviors. In G. Dawson & K.W. Fischer (Eds.), *Human behavior and the developing brain* (pp. 314-345). New York, NY: Guilford.

Birnbaum, S.G., Yuan, P.X., Wang, M., Vijayraghavan, S., Bloom, A.K., Davis, D.J., Gobeske, K.T., Sweatt, J.D., Manji, H.K., & Arnsten, A.F. (2004). Protein Kinase C overactivity impairs prefrontal cortical regulation of working memory. *Science*, *306,* 882-884.

Blaga, O.M., & Colombo, J. (2006). Visual processing and infant ocular latencies in the overlap paradigm. *Developmental Psychology, 42(6),* 1069-1076.

Blasi, G., Goldberg, T.E., Weickert, T., Das, S., Kohn, P., Zoltick, B., Bertolino, A., Callicott, J.H., Weinberger, D.R., & Mattay, V.S. (2006). Brain regions underlying response inhibition and interference monitoring and suppression. *European Journal of Neuroscience, 23,* 1658-1664.

Canfield, R.L., & Haith, M.M. (1991). Young infants' visual expectations for symmetric and asymmetric stimulus sequences. *Developmental Psychology, 27(2),* 198-208.

Canfield, R.L., & Smith, E.G. (1996). Number-based expectations and sequential enumeration by 5-month-old infants. *Developmental Psychology, 32(2),* 269-279.

Casey, B.J., & Richards, J.E. (1988). Sustained visual attention in young infants measured with an adapted version of the visual preference paradigm. *Child Development, 59*, 1514-1521.

Chao, L.L., & Kinght, R.T. (1995). Human prefrontal lesions increase distractibility to irrelevant sensory inputs. *Neuro Report, 6*, 1605-1610.

Chugani, H.T., Phelps, M.E., & Mazziotta, J.C. (1987). Positron emission tomography study of human brain functional development. *Annuals of Neurology, 22(4),* 487-497.

Clohessy, A.B. (1993). *Anticipatory eye movement learning in infants and adults: using visual cues to predict event locations*. Unpublished doctoral dissertation, University of Oregon, Eugene.

Clohessy, A.B., Posner, M.I., & Rothbart, M.K. (2001). Development of the functional visual field. *Acta Psychologica*, *106,* 51-68.

Colombo, J., & Cheatham, C.L. (2006). The emergence and basis of endogenous attention in infancy and early childhood. In R. Kail (Ed.), *Advances in Child Development and Behavior* (pp. 283-322). New York, NY: Elsevier.

Colombo, J., Mitchell, D.W., Coldren, J.T., & Atwater, J.D. (1990). Discrimination learning during the first year: stimulus and positional cues. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 16(1),* 98-108.

Courage, M.L., Reynolds, G.D., & Richards J.E. (2006). Infant's attention to patterned stimuli: developmental change from 3 to 12 months of age. *Child Development, 77(3),* 680-695.

Desimone, R., & Duncan, J. (1995). Neural mechanisms of selective visual attention. *Annual Review of Neuroscience, 18,* 193-222.

Diamond, A. (1985). Development of the ability to use recall to guide action, as indicated by infants' performance on AB. *Child Development, 56,* 868-883.

Diamond, A. (2002). Normal development of prefrontal cortex from birth to young adulthood: cognitive functions, anatomy, and biochemistry. In D.T. Stuss (Ed.), *Principles of frontal lobe function* (pp. 466-503). New York, NY: Oxford University Press.

Diamond, A. (1991a). Frontal lobe involvement in cognitive changes in the first year of life. In A.C. Petersen, & K.R. Gibson (Eds.), *Brain maturation and cognitive development: Comparative and cross-cultural perspectives* (pp. 127-180). Hawthorne, NY: Aldine de Gruyer.

Diamond, A. (1991b). Insight into the meaning of object concept development. In S. Carey, & R. Gelman (Eds.), *The Epigenesis of Mind: Essays on Biology and Cognition* (pp. 67-110). Hillsdale, NJ: Lawrence Erlbaum Associates.

Diamond, A. (1990a). The development and neural bases of memory functions as indexed by the AB and delayed response task in human infants and infant monkeys. In A. Diamond (Ed.), *The development and neural bases of higher cognitive functions.* New York: Annals of the New York Academy of Sciences, 608, 267-317.

Diamond, A. (1990b). Developmental time course in human infants and infant monkeys, and the neural bases of, inhibitory control and reaching. In A. Diamond (Ed.), *The development and neural bases of higher cognitive functions.* New York: Annals of the New York Academy of Sciences, 608, 637-676.

Diamond, A. (1990c). Rate of maturation of the hippocampus and the developmental progression of children's performance on the delayed non-matching to sample and visual comparison tasks. In A. Diamond (Ed.), *The development and neural bases of higher cognitive functions.* New York: Annals of the New York Academy of Sciences, 608, 394-427.

Diamond, A., & Doar, B. (1989). The performance of human infants on a measure of frontal cortex function, the delayed response task. *Developmental Psychobiology, 22(3),* 271-294.

Diamond, A., & Goldman-Rakic, P.S. (1989). Comparison of human infants and rehesus monkeys on the Piaget's AB task: evidence for dependence on dorsolateral prefrontal cortex. *Experimental Brain Research, 74,* 24-40.

Drewe, E.A. (1975). Go No-Go learning after frontal lobes lesions in humans. *Cortex, 11,* 8-16.

Duncan, J (2001). Frontal lobe function and the control of visual attention. In B. Jochen, K. Christof , & D.L. Joel (Eds.), *Visual attention and cortical circuits.* (pp. 69-88). Cambridge, MA, US: The MIT Press

Farroni, T., Johnson, M.H., Brockbank, M., & Simon, F. (2000). Infants' use of gaze direction to cue attention: the importance of perceived motion. *Visual cognition, 7(6),* 705-718.

Farroni, T., Mansfield, E.M., Lai, C., & Johnson, M.H. (2003). Infants perceiving and acting on the eyes: tests of an evolutionary hypothesis. *Journal of Experimental Child Psychology, 85,* 199-212.

Farroni, T., Massaccesi, S., Pividori, D., & Johnson, M.H. (2004). Gaze following in Newborns. *Infancy, 5(1),* 39-60.

Fisher, B., & Breitmeyer B. (1987). Mechanisms of visual attention revealed by saccadic eye movements. *Neuropsychologia, 25(1A),* 73-83.

Funahashi, S. (2001). Neuronal mechanisms of executive control by the prefrontal cortex. *Neuroscience Research, 39,* 147-165.

Funahashi, S., Bruce, C.J., & Goldman-Rakic, P.S. (1993). Dorsolateral prefrontal lesions and oculomotor delayed-response performance: evidence for mnemonic "scotomas". *The Journal of Neuroscience, 13(4),* 1479-1497.

Funahashi, S., Bruce, C.J., & Goldman-Rakic, P.S. (1990). Visuospatial coding in primate prefrontal neurons revealed by oculomotor paradigms. *Journal of Neurophysiology, 63(4),* 814- 831.

Funahashi, S., Bruce, C.J., & Goldman-Rakic, P.S. (1991). Neuronal activity related to saccadic eye movements in the monkey's dorsolateral prefrontal cortex. *Journal of Neurophysiology, 65(6),* 1464-1483.

Funahashi, S., Bruce, C.J., & Goldman-Rakic, P.S. (1989). Mnemonic coding of visual space in the monkey's dorsolateral prefrontal cortex. *Journal of Neurophysiology, 61(2),* 331-349.

Funashasi, S., Chafee, M.V., & Goldman-Rakic, P.S. (1993). Prefrontal neuronal activity in rhesus monkeys performing a delayed anti-saccade task. *Nature, 365,* 753-756.

Funashasi, S., & Kubota, K. (1994). Working memory and the prefrontal cortex. *Neuroscience Research, 21,* 1-11.

Gaymard, B., François, C., Ploner, C.J., Condy, C., & Rivaud-Pechoux, S. (2003). A direct prefrontotectal tract against distractibility in the human brain. *Annals of Neurology, 53(4),* 542- 545.

Gemba, H., & Sasaki, K. (1990). Potential related to no-go reaction in go/no-go hand movement with discrimination between tone stimuli of different frequencies in the monkey. *Brain Research, 537,* 340-344.

Haith, M.M. (1993). Future-oriented processes in infancy: the case of visual expectations. In C. Granrud (Ed.), *Visual Perception and Cognition in Infancy* (pp. 235-264). Mahwah, NJ: Lawrence Erlbaum Associates.

Haith, M.M., Hazan, C., & Goodman, G.S. (1988). Expectations and anticipation of dynamic visual events by 3.5-month-old babies. *Child Development, 59,* 467-479.

Hallett, P.E. (1978). Primary and secondary saccades to goals defined by instructions. *Vision Research, 18,* 1279-1296.

Hood, B.M., & Atkinson, J. (1993). Disengaging visual attention in the infant and adult. *Infant Behavior and Development, 16,* 405-422.

Hood, B.M., Willen, J.D., & Driver, J. (1998). Adult's eyes trigger shifts of visual attention in human infants. *Psychological Science, 9(2),* 131- 134.

Johnson, M. (1990a). Cortical maturation and the development of visual attention in early infancy. *Journal of Cognitive Neuroscience, 2,* 81-95.

Johnson, M. (1990b). Cortical Maturation and perceptual development. In H. Bloch, & B.K. Bertenthal (Eds.), *Sensory motor organization and development in infancy and early childhood* (pp. 145-162). Dordecht, Netherlands: Academic.

Johnson, M.H. (1994a). Cortical mechanisms of cognitive development. In J.A. Hogan, & J.J. Bolhuis (Eds.), *Causal mechanisms of behavioural development* (pp. 267-289). New York, NY: Cambridge University Press.

Johnson, M.H. (1994b). Dissociating components of visual attention: a neurodevelopmental approach. In M.J. Farah, & G. Ratcliff (Eds.), *The*

Neuropsychology of High-Level Vision (pp. 241- 268). Hillsdale, NY: Lawrence Erlbaum Associates.

Johnson, M.H. (1995a). The development of visual attention: A cognitive neuroscience perspective. In M.S. Gazzaniga (Ed.), *The Cognitive Neurosciences* (pp. 735-747). Cambridge, MA: The MIT Press.

Johnson, M.H. (1995b). The inhibition of automatic saccades in early infancy. *Developmental Psychobiology, 28(5),* 281-291.

Johnson, M. (1998). Developing the attentive brain. In R. Parasuraman (Ed.), *The attentive brain* (pp. 19-34). Cambridge, MA: MIT Press.

Johnson, M.H., Posner, M.I., & Rothbart, M.K. (1991). Components of visual orienting in early infancy: contingency learning, anticipatory, looking, and disengaging. *Journal of Cognitive Neuroscience, 3(4),* 335-344.

Johnson, M.H., Posner, M.I., & Rothbart, M.K. (1994). Facilitation of saccades toward a covertly attended location in early infancy. *Psychological Science, 5(20),* 90-93.

Jonides, J. (1981). Voluntary versus automatic control over the mind's eye's movement. In J.B. Long & A.D. Baddeley (Eds.), *Attention and performance IX* (pp. 187-203). Hillsdale, NJ: Erlbaum.

Mansfield, E.M., Farroni, T., & Johnson, M.H. (2003). Does gaze perception facilitate overt orienting? *Visual cognition, 10(1),* 7-14.

Miller, E.K., & Cohen, J.D. (2001). An integrative theory of perfrontal cortex function. *Annual Review of Neuroscience, 24,* 167-202.

Norman, D., & Schallice, T. (1986). Attention to action: willed and automatic control of behavior. In R.J. Davidson, G.E. Schwartz, & D. Shapiro (Eds.), *Conscious and Self-Regulation* (pp.). New York: University of California

Oakes, L.M. Kannass, K.N., & Shaddy, D.J. (2002). Developmental changes in endogenous control of endogenous attention: The role of target familiarity on infants' distraction latency. *Child Development, 73(6),* 1644-1655.

Oaks, L.M., & Tellinghuisen, D.J. (1994). Examining in infancy: Does it reflect active processing? *Developmental Psychology, 30(5),* 748-756.

Piaget, J. (1971). *The construction of Reality in the Child* (Margaret Cook, Trans.). New York: Ballantine Books Inc. (Original work published 1954)

Pierrot-Deseilligny, C., Rivaud, S., Gaymard, B., & Agid, Y. (1991). Cortical control of reflexive visually-guided saccades. *Brain, 114,* 1473-1485.

Ploner, C.J., Gaymard, B.M., Rivaud-Pechoux, S., & Pierrot-Deseilligny, C. (2005). The prefrontal substrate of reflexive saccade inhibition in humans. *Biological Psychiatry, 57,* 1159-1165.

Posner, M.I. (1992). Attention as a cognitive and neural system. *Current Directions in Psychological Science, 1(1),* 11-14.

Posner, M.I. (1995). Attention in cognitive neuroscience: An overview. In M.S. Gazzaniga (Ed), *The cognitive neurosciences* (pp. 615-624). Cambridge, MA, US: The MIT Press.

Quintana, J., Fuster, J.M. (1992). Mnemonic and predictive functions of cortical neurons in a memory task. *Neuro Report, 3,* 721-724.

Rabbit, P. (1997). Introduction: methodologies and models in the study of executive function. In P. Rabbit (Ed.), *Methodology of Frontal and Executive Function* (pp. 1-38). East Sussex, UK: Psychology Press.

Reznick, J.S., Chawarska, K., & Betts, S. (2000). The development of visual expectations in the first year. *Child Development, 71(5),* 1191-1204.

Robinson, N.S., McCarty, M.E., & Haith, M.M. (1988, April). *Visual Expectations in early infancy.* Paper presented at the International Conference on Infant Studies, Washington, DC.

Rose, S.A., Feldman, J.F., Jankowski, J.J., & Caro, D.M. (2002). A longitudinal study of visual expectation and reaction time in the first year of life. *Child Development, 73(1),* 47-61.

Rothbart, M.K, & Rueda, M.R. (2005). The development of effortful control. In U. Mayr, E. Awh, & S.W. Keele (Eds.), *Developing Individuality in the Human Brain* (pp 167-188). Washington, DC: American Psychological Association.

Ruff, H.A., & Capozzoli, M.C. (2003). Development of attention and distractibility in the first 4 years of life. *Developmental Psychology, 39(5), 877-890.*

Ruff, H.A., Capozzoli, M., & Saltarelli, L.M. (1996). Focused visual attention and distractibility in 10-month-old infants. *Infant behavior and development, 19*, 281-293.

Ruff, H.A., & Lawson, K.R. (1990). Development of sustained, focused attention in young children during free play. *Developmental Psychology, 26(1),* 85-93.

Ruff, H.A., & Rothbart, M.K. (1996). Attention in early development: Themes and variations. New York, NY, US: Oxford University Press.

Shaddy, D.J., & Colombo, J. (2004). Developmental changes in infant attention to dynamic and static stimuli. *Infancy, 5(3),* 355-365.

Smith, E.E., & Jonides, J. (1999). Storage and executive processes in the frontal lobes. *Science, 283,* 1657- 1661.

Sasaki, K., Gemba, H., Nambu, A., & Matsuzaki, R. (1993). No-go activity in the frontal association cortex of human subjects. *Neuroscience Research, 18,* 249-252.

Takeda, K., & Funahashi, S. (2002). Prefrontal task-related activity representing visual cue location or saccade direction in spatial working memory tasks. *Journal of Neurophysiology, 87,* 567-588.

Tsujimoto, T., Ogawa, M., Nishikawa, S., Tsukada, H., Kakiuchi, T., & Sasaki, K., (1997). Activation of the prefrontal, occipital, and parietal cortices during go/no-go discrimination tasks in the monkeys as revealed by positron emission tomography. *Neuroscience Letters, 224,* 111-114.

Wentworth, N., & Haith, M.M. (1992). Event-specific expectations of 2- and 3-month-old infants. *Developmental Psychology, 28(5),* 842-850.

Wentworth, N., & Haith, M.M. (1998). Infants' acquisition of spatiotemporal expectations. *Developmental Psychology, 34(2)*, 247-257.

Wentworth, N., Haith, M.M., & Hood, R. (2002). Spatiotemporal regularity and interevent contingencies as information for infants' visual expectations. *Infancy, 3(3),* 303-321.

West, R.L. (1996). An application of Prefrontal Cortex Function Theory to Cognitive Aging. *Psychological Bulletin, 120 (2),* 272-292.

White, I.M., & Wise, S.P. (1999). Rule-dependent neuronal activity in the prefrontal cortex. *Experimental Brain Research, 126,* 315-335.

Woods, D.L., & Knight, R.T. (1986). Electrophysiological evidence of increased distractibility after dorsolateral prefrontal lesions. *Neurology, 36,* 212-216.

Appendix A

Approved by the Human Subjects Committee University of Kansas, Lawrence Campus (HSCL). Approval expires one year from 10/3/06.

The University of Kansas
Infant Cognition Research Program

KU Edwards Campus/Regents Center Room 16
Overland Park, Kansas 66213 ● (913) 897-8590 ● (785) 312-5345

INFORMED CONSENT STATEMENT
Time Perception and Processing in Human Infants

INTRODUCTION

The Department of Psychology at the University of Kansas supports the practice of protection for human subjects participating in research. The following information is provided for you to decide whether you wish for you child to participate in the present study. You may refuse to sign this form and not participate in this study. You should be aware that even if you agree to participate, you are free to withdraw your child at any time. If you do withdraw from this study, it will not affect you or your child's relationship with this unit, the services it may provide you or your child, or the University Kansas.

PURPOSE OF THE STUDY

The purpose of our research is to gather information on the development of attention during the first year of life. Specifically, in this study, we are interested in examining difference between 4 and 9 month-old infants' abilities to control eye movements. We would like to know if there are differences in infants' abilities to use the content of a picture to move their eyes to varying locations.

PROCEDURES

Your child will be placed in a car seat while we present him/her with a series of pictures. While the pictures are being presented we will monitor your child's heart rate as well as their eye movements. At the end of the session, we will be able give you a brief description of your child's performance, and ask that you fill out a questionnaire that pertains to your child's health, background, and environment. The entire visit should take no more than 30 minutes, although the actual testing of your child usually takes no more than 15 minutes in length. Upon completion of the entire project, we will send you a general report of our results.

RISKS

Please be assured that none of our procedures or measurements present any risk to your child.

BENEFITS

Although it is unlikely that this study will provide any direct benefit to you or your child, your participation will make an important contribution toward our understanding of child development.

INFORMATION TO BE COLLECTED

To perform this study, researchers will collect information about you and your child. This information will be obtained from a health and background questionnaire administered prior to the beginning of the session. Also, information will be collected from the study activities that are listed in the Procedures section of this consent form.

It is our policy to protect the confidentiality of all our participants. Your infant's name will be coded by a confidential number and will not appear in any test forms, computerized records, analyses, or publications involved with this study.

All video recordings will be stored under a confidential number on a DVD. Upon completion of the study the DVDs will be coded and stored at our research facility in Lawrence.

The information collected about you and your child (including video recordings) will be used by Dr. John Colombo and the laboratory and staff members of the Infant Cognition Study Center. In addition, Dr. John Colombo may share the information gathered in this study with investigators at the University of Kansas involved in the Center for Behavioral Neuroscience in Communicative Disorders. The researchers will not share information about you or your child with anyone not specified above unless required by law or unless you give written permission.

Permission granted on this date to use and disclose your information remains in effect indefinitely. By signing this form you give permission for the use and disclosure of your information for purposes of this study at any time in the future.

One of the members of the KU Infant Study Center staff will be happy to answer any questions you might have about the purpose, procedures of the study, or your rights. Do not hesitate to call the principal investigators, Dr. John Colombo (Kansas City telephone: 913-897-8590, Lawrence telephone 785-864-9841), should any questions arise after you have left the laboratory.

REFUSAL TO SIGN CONSENT AND AUTHORIZATION

You are not required to sign this Consent and Authorization form and you may refuse to do so without affecting your or your child's rights to any services you or your child are receiving or may receive from the University of Kansas or to participate in any programs or events of the University of Kansas. However, if you refuse to sign, you and your child cannot participate in this study.

CANCELLING THIS CONSENT AND AUTHORIZATION

You may withdraw your consent to have your child participate in this study at any time. You also have the right to cancel your permission to use and disclose information collected about you and your child, in writing, at any time, by sending your written request to: John Colombo, PhD, University of Kansas, Department of Psychology, 426 Fraser Hall, 1415 Jayhawk Blvd., Lawrence, KS 66045. If you cancel your permission to use your and your child's information, the researchers will stop collecting additional information about you and your child. However, the research team may use and disclose information that was gathered before they received your cancellation, as described above.

PARTICIPANT CERTIFICATION:

I have read this Consent and Authorization form. I have had the opportunity to ask, and I have received answers to, any questions I had regarding the study and the use and disclosure of information about my child and me for the study. I understand that if I have any additional questions about my child's and my rights as a research participant, I may call (785) 864-7429 or write to the Human Subjects Committee Lawrence Campus (HSCL), University of Kansas, 2385 Irving Hill Road, Lawrence, KS 66045-7563, email dhann@ku.edu.

I agree to allow my child, ___________________________, to take part in this study as a research participant. I further agree to the uses and disclosures of my child's and my information as described above. By my signature I affirm that I am at least 18 years old and that I have received a copy of this Consent and Authorization form.

_______________________________ ______________________ _____________

Print Parent/Guardian of Participant   Relationship to child   Date

_________________________________ _________________________________

Parent/Guardian Signature   Research Staff Signature

_______ *I agree to allow the recording of this procedure to be used for professional or educational purposes. For example, parts of the session may be shown at seminars and scientific conferences. If any part of the session is used total anonymity will be kept.*

Appendix B

University of Kansas

Infant Cognition Research Program

Health and Background Questionnaire

Lab Use Only	
Postnatal age	_____days
Postconceptional age	_____days
Birthweight Conversion	_____days
Current Weight Conversion	_____days

Baby's Dates and Weights

Birthdate: ____/____/____
Due Date: ____/____/____
Birth Weight: ____lbs____oz
Current Weight: ____lbs____oz

Birth Information

_____ Normal/Vaginal
_____ C-Section
If it was a C-section, was it _____emergency or _____elective
Reason for emergency C-section: ____

Medical Information

Difficulties during Pregnancy?
_____ For Mother Explain: ____
_____ For Infant Explain: ____
Difficulties during Labor?
_____ For Mother Explain: ____
_____ For Infant Explain: ____

Length of Hospital Stay after Birth ______ days or hours (Circle one)

Baby's Current Health (Mark any that apply)

_____ Has a cold
_____ Running a temperature
_____ Has and ear infection
_____ Is on medication. Please specify: ______________________________________
_____ Has had shots within one week of appointment
_____ Has been rehospitalized since birth
If so, for what condition? ____
For how long? ____
_____ Has chronic condition Please specify: _______________________________

Baby has had _____ ear infections since birth.

Lab Use Only	
Has been awake for	_____min
Has not been fed for	_____min

Today's most recent nap ended at __________.
Today's most recent feed ended at __________.

Baby is currently fed (check all that apply):

_____ Formula _____ Breastmilk _____ Solid Food
If you are not currently breastfeeding your baby…
Was your baby ever breastfed? Yes _____ No _____
If yes, for how long? ___________________________

KU Infant Cognition Health Questionnaire

Caregiving Arrangements

Infant is in daycare for _____ hours per week. (If not in daycare, enter zero)

If in daycare, what type:

_____ Daycare center

_____ Home-based care

_____ Your home (i.e., *you* run a daycare for other children

_____ A relative's home (e.g., grandparent, aunt, etc.)

_____ Someone else's home

_____ Private caretaker/nanny/au pair in your home

Home Environment

How many siblings living at home full-time? _____ (include half-siblings)

Ages of these siblings ____

How many siblings visit or live at home part-time? _____

Ages of these siblings ____

Approximate frequency and length of visit/stay: _______________________________________

_____ Individuals other than the baby's mother, father, siblings living at home full-time

_____grandmother _____grandfather

_____aunt _____uncle

_____friend _____other (______________________)

Race/Ethnicity

What is the race/ethnicity of your baby? (Please Check all that apply)

______Hispanic or Latino

______American Indian or Alaska Native

______Asian

______Black or African American

______Native Hawaiian or Other Pacific Islander

______White

______ Check here if you do not wish to provide this information

Gender/Sex

What is the sex/gender of your baby?

______Male

______Female

	Age	High School	Jr. Coll.	College or	Grad Degree (MA, PhD, MD, JD,	Occupation
		Please indicate highest level of education completed.				
Mother		1 2 3	1 2	1 2 3 4		
Father		1 2 3	1 2	1 2 3 4		

Lab Use Only

Infant's Code:___________ Arrived at lab asleep: _____________

Today's Date:___/___/____ Fed prior to session:_______________

Appointment Time:_____:_____ Changed prior to session:___________

HQ filled out by Mom Dad Rel Care Other

Session coded by _____

_____DVD DVD#_____ Counter__________

_____HR _____ Fix _____ Rel _____ET