

**Looking and Listening Patterns in 4- and 8- Month-Old Infants:
Correspondence between Measures of Attention across Modalities**

Megan Elizabeth McIlreavy, M.S.

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Dr. Robin Panneton Cooper, Committee Chair

Dr. Martha Ann Bell, Committee Member

Dr. Lee Cooper, Committee Member

Dr. Julie Dunsmore, Committee Member

Dr. Robert Stephens, Committee Member

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ABSTRACT

The development of perceptual-cognitive processes during infancy has been traditionally studied using visual habituation and paired-comparison techniques. There has been extensive work within the field of infant attention that has focused on the development of visual attention. Within this field, it has been well established that there are two distinct classifications of infants' visual behavior; infants with short visual fixations who perform well in a recognition task following familiarization and infants with long visual fixation with impaired performance. There are two hypotheses for the differences underlying these groups. First, that visual fixation duration is reflective of the speed of information processing such that long-looking infants process information more slowly than short-looking infants. The second hypothesis is that infants who are long-looking have difficulty disengaging and shifting their attention to another location. There has not been any work exploring how these differences manifest themselves in other modalities. Thus, this project has three purposes: (1) to explore whether group differences emerge in an auditory recognition task similar to those found in the visual recognition phase of the paired-comparison task, (2) to better understand how performance differences in the visual task correspond to any observed differences in an auditory task, and (3) to identify any potential mechanisms which may account for the observed differences in group performance on an auditory task.

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Take a trip
Take a look
Take a sip
Take it in

Take a lift
Take your time
Take a gift
Take ten

Take a break
Take for granted
Take care
Take a friend

Take heart
Take forever
Take me
Take my hand

Chapter 1

Introduction

With respect to early human development, “attention” is an emergent process in which different manifestations of perceptual-cognitive processes become evident across the first postnatal year, allowing infants to better manage large amounts of stimulation. The importance of attention for adaptive behavior is fundamental to our everyday functioning, which generates many compelling questions about its development and the sources of individual variability in attentional capacities. While there is not one uniformly accepted definition of attention, there is agreement that attention is not a unitary phenomenon, but a complex set of perceptual/cognitive functions that depend upon many underlying processes (Posner & Boies, 1971; Pribram & McGuinness, 1975; Porges, 1976; Ruff & Rothbart, 1996). So far, there has been extensive work investigating the development of infants’ visual attention across the first year, but relatively little is known about the correspondence of attention occurring across modalities. Of particular interest is the exploration of infants’ auditory attentional abilities and the congruence of performance between the visual and auditory attentional systems. Given that attention is not specific to one sensory system, there is a need to broaden our understanding of the development of infant attention beyond what is known within the visual domain.

Developmental Changes in Attention across the First Year

From the first few days of life, infants selectively attend to events in their environment, and look longer to certain events primarily as a function of the intensity of the stimulation, such as size, contrast or brightness (Fantz, 1961). As infants develop, so do their attentional responses, and appear to be more dependent upon the pattern and form of the stimulus rather than driven by the intensity alone (Ruff & Turkewitz, 1975, 1979). Over the rest of the first postnatal year, a large part of infants’ attention is governed by the novelty of objects and the events they encounter. Importantly, there are three time-related aspects of attentional processing that undergo developmental change; the initiation of attention (stimulus orienting), sustaining or the maintenance of attention, and the disengagement or termination of attentional processing.

The initiation of attention (often called “orienting”) is relatively automatic and is important as it involves both alertness to and selection of potentially important information. This system is fully developed in the first 2 to 3 months of life (Graham, Anthony, & Ziegler, 1983). The orienting phase may be followed by a period of sustained attention if the event is interesting enough for there to be further exploration. This ability to sustain attention for an extended period of time increases across the first postnatal year and enables infants to acquire new information and gain experience with the objects and events occurring in the present environment. Lastly, it is important for infants to be able to shift their attentional focus from one source to another. For young infants (younger than 4 months) this can be quite difficult, particularly if the event is highly salient. “Obligatory attention” occurs when young infants become visually captured by an event and can not shift their attention toward another location, even though they may not necessarily be processing the event. By 4-months of age, infants have greater flexibility in shifting their attention and can also more readily disengage their looking behavior

(Johnson, Posner, & Rothbart, 1991; Posner, Rothbart, Gerardi, & Thomas-Thrapp, 1997). Taken together, Ruff and Rothbart (1996) suggest that these components work together as the orienting/investigative system which governs infants' attention throughout the first postnatal year until a new system of attention emerges (beginning in early toddlerhood) and modulates the control of attention.

Across the first year, there are also differences in fixation duration (or the length at which infants will look at a display), as younger infants attend for longer periods of time to events compared to older infants (Colombo & Mitchell, 1990). To better demonstrate, Colombo, Harlan, and Mitchell (1999) conducted a comprehensive review of the data on the development of look duration across the first postnatal year. This yielded evidence for three fairly distinct phases: a) a period from birth to 8-10 weeks during which look durations steadily increased, b) a period of decline in look duration from 3 to 6 months of age, and c) a period from 7 months onward when look duration stabilizes or may even gradually increase (see Figure 1). In order to more fully understand infants' attentional abilities, it becomes necessary to clearly define attention, as the understanding of attentional processes can be approached from different theoretical orientations; behavioral, psychophysiological, and developmental cognitive neuroscience.

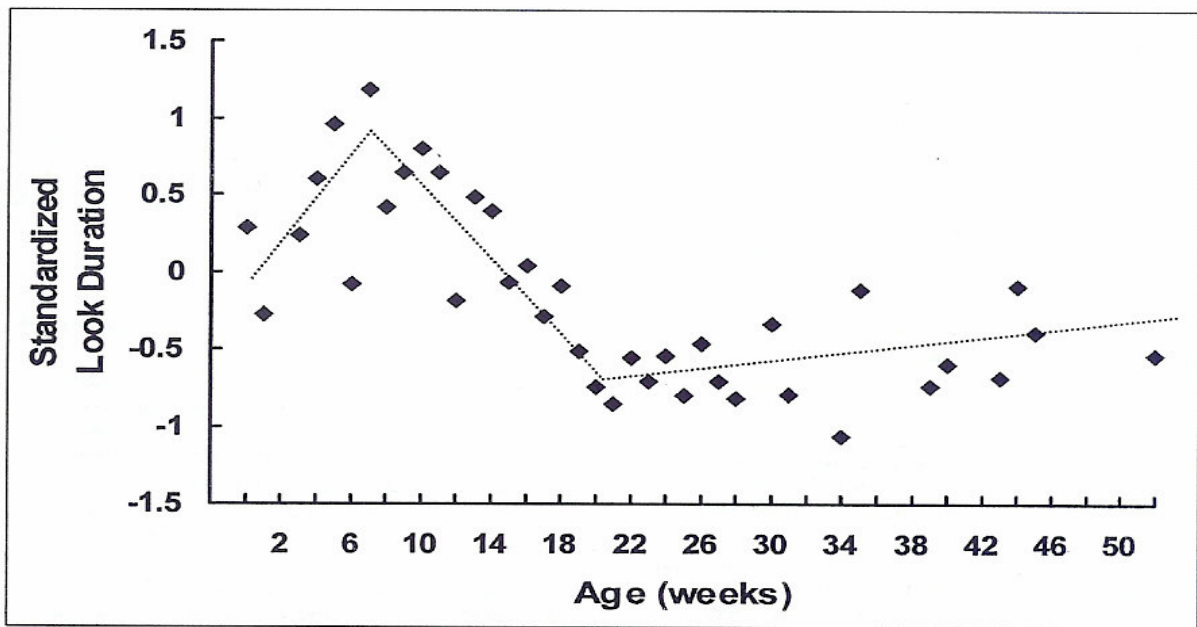


Figure 1: The developmental course of look duration in infants adapted from Colombo, Harlan, & Mitchell (1999)

Behavioral Definition of Attention

Ruff and Rothbart (1996) offer an infant model that is composed of a three-part definition of attention. The first component is that of selectivity of processing, which is essential for partitioning multiple, concurrent sources of stimulation occurring within the environment. The focus of selective attention can either be internally or externally driven, is manifested across sensory modalities, and is influenced by perceptual experiences leading to greater differentiation of objects and events. While young infants are limited

by the capacities of their perceptual systems, they are able to demonstrate an orienting response (the reflexive movement of sensors toward a given source of external information) which consequently governs much of their attentional selectivity.

As mentioned earlier, young infants are heavily influenced by the perceived novelty of events (Posner & Rothbart, 1981). A preference for novelty (i.e. paying more attention to a new object or event compared to a familiar one) often demonstrates infants' abilities to categorize and discriminate objects and events. Importantly, while novelty preferences are routinely observed, often events which are more meaningful to the infant will continue to elicit familiarity preferences (e.g., mother's face, voice, smell). Due to inconsistencies within the infancy literature regarding familiarity and novelty preferences, Roder, Bushnell, and Sasseville (2000) systematically investigated these outcomes and show that infants will selectively attend to a familiar event prior to showing preference for a novel one. Thus, familiarity preferences can be viewed as reflecting the early stages of information processing. Interestingly, the strength of novelty preferences observed in infancy have been significantly correlated with traditional measures of IQ at later ages (see meta-analytic reviews by Bornstein & Sigman, 1986, and McCall & Carriger, 1993).

The second component of attention is the state of engagement, which either facilitates or impedes the processing of external stimuli. One way in which these states can be identified is through the utility of physiological measures that monitor the internal changes occurring within an organism. These changes may mirror those that are readily observable in behavioral measures of attentional engagement, although sometimes physiological measures may be more sensitive in detecting a change in an infant's attentional state. Sustained attention (or focused attention) is a state most interesting to many researchers since it is a time during which infants are most adept at extracting important information about an event, with multiple factors being responsible for sustaining their attention. There are developmental differences in sustained attention occurring in infancy over the first year, with younger infants spending significantly less time in focused attention, suggesting that they are less efficient in their processing capabilities.

Focused attention occurs when sensory receptors (e.g. eyes) are directed more or less exclusively toward one target or task. During episodes of focused attention, infants are less distractible by other sources of stimulation (Richards & Casey, 1991). The more narrowly focused the attention and the more salient the target activity, the less likely a distracter will interfere with ongoing processing. However, there are a variety of factors that lead to the interference of attention, resulting in inattention and even attention deficit disorder. Stimulus orienting and sustained attention are two basic attentional processes which are fully developed by the end of the second year.

The final component defining attention is executive control. Because selectivity and state are tightly coupled constructs of attention, this system serves a regulatory function in order to allow the individual to effectively interact within the environment. These executive functions manage where attention is allocated, the level of engagement dedicated to the activity, as well as aid in the preparation for subsequent behavior. It is this component that helps to establish organization and place priority on current goals (Ruff & Rothbart, 1996). Awareness of this organization can either be conscious (as we purposefully decide which activities are of the highest priority) or unconscious (as some

events are highly salient and command our attention while others are ignored or not detected). Unlike the other two processes, executive control continues to develop throughout mid-adolescence. In an attempt to understand the development of infant attention, behavioral and physiological components are individually informative yet, when attention is studied utilizing both measures concurrently, a more rich description of underlying processes of this construct can be offered.

Attention Defined from a Physiological Perspective

For many years, visual behavior was the predominant index of infant attention, however, using discrete 'looking' measures for assessing the broader construct may only yield a partial view of this process because attention is not just influenced by event properties but also by internal factors that reflect the functioning of the infant's general arousal system. This nonspecific arousal system helps to initiate attention, sustain attention, and maintain a vigilant state (Richards, 2001). Heart rate (HR) change is one valuable index of infant attention, with many studies of infant attention and cognitive functioning now routinely including psychophysiological measures to better establish the qualities of attentional processing (Richards, 1985a, b; 1997). Richards and Casey (1992) have provided a model that distinguishes systematic changes in HR within an attentional episode (as would be defined by visual behavior) that are reflective of the influence of the arousal system via parasympathetic nervous system control. Their model specifies five attentional phases that infants cycle through when they are looking at a display (see Figure 2). Of particular interest are the stimulus orienting (SO), sustained attention (SA), and pre-attention termination (PT) phases.

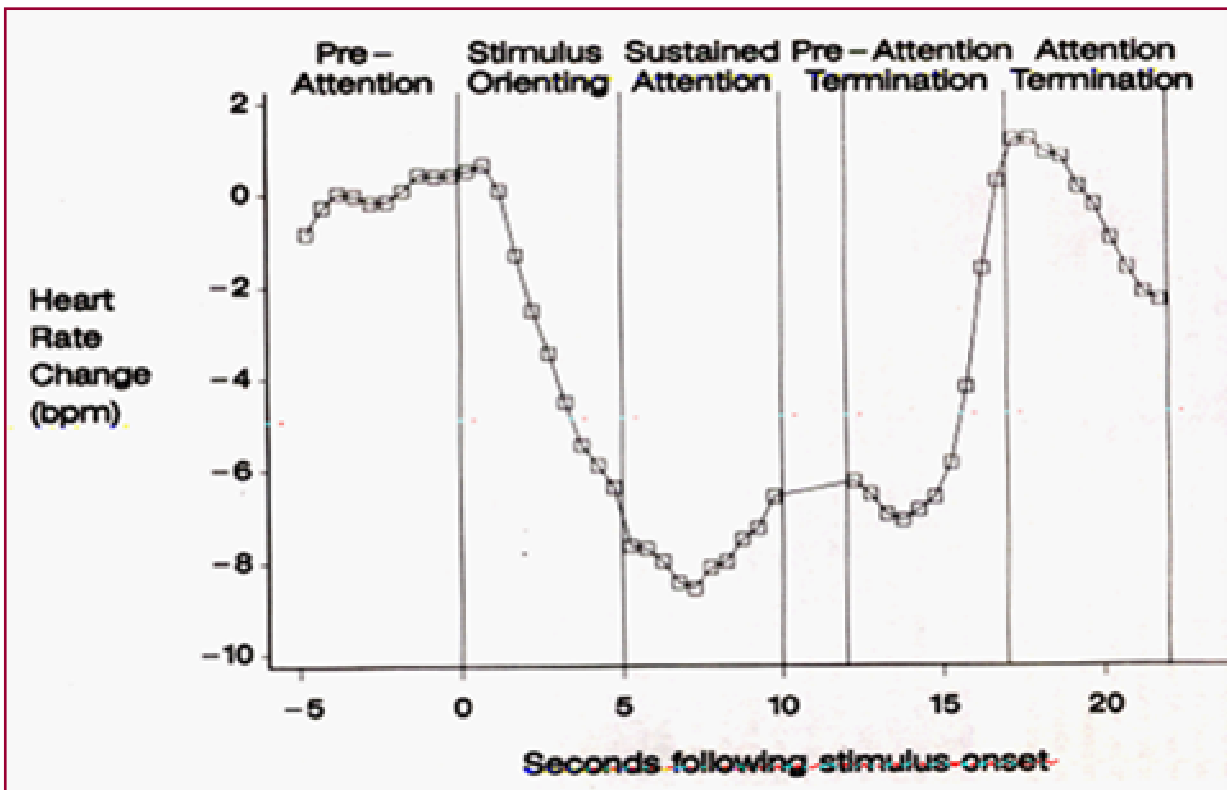


Figure 2: Heart Rate model adapted from Richards and Casey (1992)

Stimulus orienting or attention capture is relatively automatic and strongly dependent on the physical characteristics of events (e.g. intensity, novelty, complexity). It is marked by heart rate deceleration, with the magnitude of deceleration being age related (e.g. greater deceleration shown in older infants). The period of *sustained attention* is defined when HR is 50% slower than it was during the baseline acquisition. The arousal system of the brain controls the heart rate changes that originate from cardioinhibitory centers in the orbitofrontal cortex. These centers act through the parasympathetic nervous system to slow heart rate when the arousal system is engaged. The degree of deceleration of heart rate during SA is thought to reflect the depth of attention (Richards, 2001). In this phase, heart rate is not only slower, but also less variable, and respiration amplitude and body movements also decrease (Jennings, 1986). The duration of SA is highly dependent on the state of the infant, novelty of the display, display complexity, and characteristics of the infant (Richards & Casey, 1992). Sustained attention not only enables the infant to extract more detailed information about the event, but also undergoes the most developmental change with age. That is, infants become more efficient in their attentional control over time. Finally, during *pre-attention termination*, infants are still visually fixating but do not have the same kind of autonomic activity invested in stimulus processing (as is seen in SA). During PT, heart rate begins to accelerate and is accompanied by heightened levels of distractibility, lack of acquisition of stimulus information, and lack of selective modality effects (Richards, 2001).

Cognitive Neuroscience of Attention

With regard to attention, there have been three neural networks that have been identified and each are involved in the selective aspects of attention in different ways (for a review see Posner & Peterson, 1990). The first is the *posterior attention network* which is involved in stimulus orienting and subsequently directs attention to relevant locations and sources of information occurring within the environment. Anatomically, this network involves portions of the parietal cortex, associated thalamic areas of the pulvinar and reticular nucleus, and parts of the midbrain's superior colliculus (Rothbart, Derryberry, & Posner, 1994). These areas work together to direct and coordinate attention toward one spatial location. Additionally, this system has close anatomical connections to anterior attention networks and to arousal or vigilance systems (Posner & Peterson, 1990).

The second system is the *anterior attention network* which functionally has been termed "executive" as it includes emotional, attentional, and motor aspects of behavior (Vogt, Finch, & Olsen, 1992). Areas of the midprefrontal cortex, including the anterior cingulate gyrus and a closely related more superior supplementary motor area are active in a variety of situations including the detection of events and the effortful control of behavior (Posner & Peterson, 1990; Posner & Rothbart, 1991; Rothbart, Derryberry, & Posner, 1994; Vogt et al., 1992). This system predominately integrates thoughts and behavior and exerts control on emotional experience and expression. The anterior attention system is emergent toward the end of the first postnatal life as infants are able to begin to plan activity, self-direct behavior, as well as inhibit dominant behavioral responses (Ruff & Rothbart, 1996). This attentional system has a strong tie to emotional control, in that individuals who have greater flexibility in their attentional skills are better able to regulate their emotional arousal, as they can shift their attention away from sources of distress.

Working in conjunction with the *anterior attentional network* is the third selective attention system or the *vigilance system* (Posner & Peterson, 1990). This system enables individuals the ability to maintain an alert state particularly in tasks requiring them to respond to select or infrequent targets that are embedded in irrelevant information (i.e. reaction time task). Anatomically, this system involves locus coeruleus noradrenergic input to the cortex (for a review see Harley, 1987) with particular neural activity being identified within the right lateral frontal lobe. This attentional network has an effect on both the posterior and anterior attentional systems by enhancing the ability to recognize objects and events in the face of accumulating information and better enabling an individual to detect and inhibit dominant behavioral responses.

As in all aspects of development, there is variation that can be observed in response to environmental events. Variations of attentional abilities (at all levels) are interesting, although attempting to identify the contributing sources of this variation can be empirically difficult (Thelen, 1992). The current literature predominately attributes the sources of variability in attention to individual differences, and despite the limitations of this perspective as it neglects the possibility for there to be other factors contributing to different development trajectories, it is an issue necessary to be addressed in order to more fully appreciate the current status of the field.

Individual Differences in Attention

The term “individual differences” refers to behavioral variation among individuals that transcends both time and context (Ruff & Rothbart, 1996). On a fundamental level, there are two sources for this variability that are important to early development: organismic variables, the characteristics that are embodied within an individual; and external variables, the characteristics of the child’s surroundings that influence developmental outcome. Researchers interested in individual differences primarily utilize two different designs in their investigations. The first is to use correlational techniques that assess the degree of association between measurements taken at different times or in different contexts. The second method is to establish subgroups of children based upon the classification of behavior at one point in time and then observe them at another time or in different situations.

With regard to individual differences in attention, infants vary in the readiness in which that they react to environmental stimulation, the amount and degree of sustained attention, and their ability to actively focus on objects, events and activities (Ruff & Rothbart, 1996). There are many sources of variability that could contribute to observed individual differences; speed of learning, amount of information being processed, temperament, motivation, inhibitory control, and self-regulation abilities. Further, variation in attentiveness is likely to be related to differences in physiology and neurological organization, which are differences that are assumed to be stable across extended periods of time. Heart rate (HR) and heart rate variability are physiological measures of individual differences in the continuous feedback between the central nervous system and peripheral autonomic receptors.

Much of the work in the field of infant attention (specifically visual attention) has been dedicated to better understanding the observed individual differences in the duration of infants’ visual fixations. There is a counterintuitive association between attention and the duration of visual fixation in infancy; that is infants who appear to be spending a long time attending to a display have a propensity to perform poorly on recognition tasks.

Studies which examine visual attention and recognition memory simultaneously, lend insight into the overall cognitive activity involved in information processing (Reynolds & Richards, 2004). Performance on visual recognition memory tasks has proven to be a sensitive indicator for a variety of conditions that are associated with later risk of cognitive difficulties including prematurity, Down's syndrome, failure to thrive, malnutrition, non-optimal perinatal events, and exposure to chemical teratogens (Jacobson, Fein, Jacobson, Schwartz, & Dowler, 1985; Miranda & Fantz, 1974; Rose, 1980, 1983, 1994; Rose, Feldman, McCarton, & Wolfson, 1988). Additionally, visual recognition memory in infancy has been found to be a significant predictor of general cognitive ability in later childhood (e.g. Rose & Feldman, 1995; Rose, Feldman & Wallace, 1992; Rose, Feldman, Wallace, & Cohen, 1991; for a review, see McCall & Carriger, 1993). Due to the predictive ability of infant performance, it becomes seemingly advantageous to identify various processes contributing to the observed differences in recognition performance. Because recognition memory is contingent upon visual attention, the visual modality has been the predominate focus for much of the work investigating the development of infant attention.

Visual Attention and Recognition Memory

Visual attention and recognition memory are closely related constructs that traditionally have been studied through the utilization of a paired-comparison task (Fantz, 1956; Fagan, 1970). This task has reliably established individual differences in infant cognition, as infants who are in an attentive state (as compared to an inattentive or a casual state of attending) during the familiarization period will differentially attend to events presented in the test phase of the task. This task first begins with a familiarization phase in which an infant is presented with a visual display. If the familiarization phase is infant controlled (i.e. each trial lasts as long as the baby looks at the event and trials continue until habituation has occurred), the variation in the amount of exposure needed to reach habituation can be attributed to individual differences in infants' attentional processing abilities. In contrast, the familiarization phase could consist of a fixed trial procedure where the infant is presented with a predetermined number of trials and the experimenter controls the amount of time that the infant is exposed to the display. With a fixed trial procedure an infant may or may not fully habituate to the event. In either case, once the familiarization criterion has been met, infants are concurrently presented with two displays; one display is the same (or similar on some dimension as in the familiarization phase), and the other display is novel (or different on some dimension). Novelty preferences are typically observed if the infant is able to adequately process the familiarization stimulus and recognize it during the test phase. Recognition memory is inferred from differential responsiveness to the testing events and is measured by composing a novelty score, or the percentage of looking time during the test phase that is directed toward the novel target (Fagan, 1974; Rose & Feldman, 1990).

Within the field of infant visual attention, individual differences in attentional processing have been reliably established based upon performance in the paired-comparison task. Beginning as early as 14 weeks of age, the amount of time that an infant will visually attend to an event has resulted in the identification of two distinct classifications of infant behavior; long-lookers and short lookers. These classifications of infant behavior can be based upon: 1) the overall amount of time that an infant will look

at a display, 2) the longest look (peak fixation time) during a specified period of time or, 3) the length of the first look at the display once it has been presented (Colombo, 1993).

Visual fixation duration is thought to be reflective of the amount and quality of information being processed; as short-looking infants process information faster and more efficiently (Colombo, 1993; Colombo et al., 1991; Freese et al., 1993; Jankowski & Rose, 1997; Rose, Futterweit, & Jankowski, 1999). Additionally, short-lookers appear to utilize a more efficient, global to local strategy of processing information (e.g. they process the overall configuration of the display first and then the finer details) whereas long-looking infants first process the local elements and then the global features (Colombo, Freese et al., 1995; Colombo, Frick, Ryther, & Gifford, 1996; Frick & Colombo, 1996; Stoecker, Colombo, Frick, & Allen, 1998). It has also been established that short- and long-lookers differ in their breadth of visual inspection (Bronson, 1991; Jankowski & Rose, 1997). Infants who scanned the display more broadly tended to have a processing edge, as their fixations were shorter in duration and they spent less time inspecting any one element of the display before switching to inspect another element. Work within the field has devoted much effort in understanding the factors that distinguish these group differences. So far, two potential sources have been identified; speed of encoding and disengagement.

Initially, as an extension of Sokolov's comparator model (1963), it was thought that group differences in performance were attributable to the processing speed of visual information. Encoding speed refers to the amount of time needed to sufficiently assimilate information and later recognize it. Therefore, decrements in encoding speed were interpreted as reflections of how quickly the infant was able to form an internal representation ("engram") of the event. According to this model, brief fixations implied that the event had been completely represented (a match between an existing engram and the event) while long look durations indicated either a mismatch between the existing engram and the event or a lack of an existing engram altogether. This model seemed to fit nicely with the well established findings documenting the decline of infants' look duration across the first year. It also provided a means for interpreting the performance differences observed between long- and short-looking infants; in that, infants who engaged in prolonged looking behavior were seen as slower processors both within and across age.

Additional work began investigating long-lookers' familiarity preferences that were observed in the test phase of the paired-comparison procedure. These preferences were thought to be attributable to the partial processing of the familiar display; infants were not fully encoding the entire display (Colombo, Mitchell, & Horowitz, 1988; Fagan, 1974; Rose, 1983). This hypothesis arose from the contention that brief exposures in the familiarization phase does not allow for complete processing of the event information and thus infants exhibit a familiarity preference on the test trials in an attempt to more fully complete the processing of the event (Rose et al., 1982). To further address this issue, Richards (1997) suggested the intensity of cognitive processing occurring during the familiarization phase would impact recognition performance based upon which attentional phase the events were presented. More specifically, he predicted that if the event was presented during sustained attention, infants would be able to more completely process the event and show better performance on the test trials. To address this issue, HR was monitored as infants at 14-, 20-, and 26-weeks were first presented with a short

video clip of Sesame Street. Once HR decelerated to a defined attentional phase, a visual pattern was presented (the duration of visual patterns presented in each attentional phase were also varied). Results indicated that when the familiarization phase of the stimulus presentation was limited to sustained attention, infants at 20- and 26 weeks showed a preference for the novel stimulus. This is suggestive that the state of engagement (as defined by attentional phases in HR) may augment the amount of information that is encoded, as the presentation of stimulus information in sustained attention improved recognition performance.

More recently, infants' disengagement abilities have provided a more comprehensive understanding of infants' visual behavioral patterns beyond that of the speed of encoding hypothesis. To begin with, Frick, Colombo, and Saxon (1999) found that short-lookers more readily disengage their attention than long-lookers. In this study, 3- and 4-month-olds were presented with a central display followed by a peripheral one. There were two conditions in which the peripheral display was presented: competition (both displays were being presented at the same time) and noncompetition (the peripheral display came on once the central target went off). It was found that all infants had longer latencies to initiate a look toward the peripheral display in the competition trials but the infants classified as long-looking took significantly longer to disengage and shift their attention than the short-lookers. There were no group differences observed on the noncompetition trials. Importantly, the look durations in the pretest were strongly correlated ($r = +.62$) with the latency to initiate eye movements when disengagement was necessary. These behavioral findings are suggestive of disengagement difficulties for long-looking infants.

As a natural extension of this area of work, Jankowski, Rose, and Feldman (2001) sought to determine whether infants' preferred strategy for visual inspection could be modified, specifically for long-looking infants. These authors sought to induce disengagement and facilitate a wider distribution of stimulus inspection in order to ascertain implications for information processing. To examine the modifiability of 5-month-olds' visual attention, the display was divided into four equal parts and each quadrant was successively illuminated for 1 s during the familiarization phase of the paired-comparison task. This highlighting technique was utilized in attempt to encourage disengagement and increase shifting across quadrants for the long-looking infants. The results did support the effectiveness of the spotlighting technique as long-lookers attention was modified in such a way that it became indistinguishable from that of their short-looking counterparts and subsequently induced novelty preferences during test trials. These findings also support Bronson's (1991) contention that the distribution of attention affects processing; long-looking infants had shorter and more numerous looks and shifts during familiarization which improved their processing abilities. To provide further support that disengagement abilities are responsible for the observed group differences in infants' attentional performance, there has been much work utilizing physiological measures to better address this hypothesis.

Physiological Differences in Visual Attention

The cognitive neuroscience perspective propelled further investigation that explored infant visual behavior as a composite of a variety of attentional states (e.g. orienting and engagement of attention, sustained attention, and disengagement) as well as the brain-based mechanisms that would explain why prolonged look duration was

associated with slower speed or efficiency of encoding. As a result, long-looking infants tend to perseverate on certain visual features and are unable to inhibit or disengage their attention and shift it elsewhere (see Hood, 1995). Difficulty in attentional disengagement has been found to be a function of the posterior attention network (Posner & Petersen, 1990; Posner, Rothbart, & Thomas-Thrapp, 1997).

Additionally, studies utilizing HR measures have shown support for the disengagement hypothesis. For example, Colombo, Frick, Gorman, and Casebolt (1997) analyzed the infants' longest look during a standard, infant-controlled habituation session and broke it down into three points of analysis. Infants were first divided into long-looking and short-looking groups and then HR change (relative to prestimulus baseline) during 1-second epochs were compared at three points in time: 1) immediately following the onset of the look, 2) at the lowest point of deceleration during the look, and 3) immediately prior to the infant's termination of the look. Results found no group differences (in HR change) following the onsets of the look or during the deceleration of the look (these two points were reminiscent of Richards' and Casey's (1992) stimulus orienting and sustained attention phase). Importantly, there were marked differences on the last point of analysis (attention termination), as infants with short looking patterns terminated their looking while their HR was at, or below the baseline level but contrastively, long-looking infants did not terminate their looking until their HR was significantly above baseline levels. This suggests that prolonged looking might reflect an extended period of attention termination, and thus difficulty with disengagement (Colombo, 2004; see Figure 3).

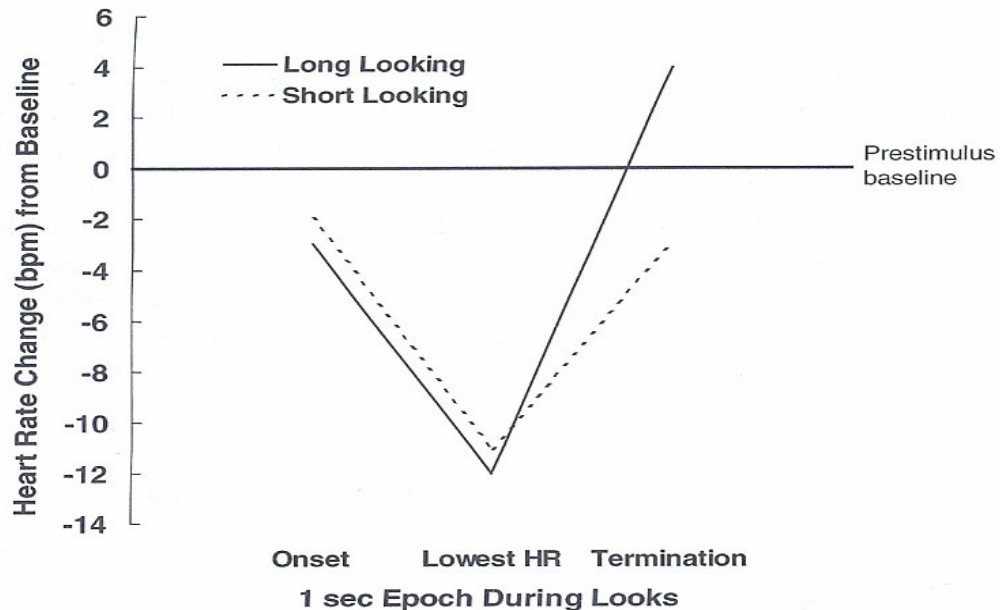


Figure 3: Colombo et al. (1997) results adapted from Colombo (2004)

The association between look duration and attention termination/disengagement was tested directly (Colombo, Richman, Shaddy, Greenhoot, & Maikranz, 2001) to

determine the degree to which look duration and phases of attention (orienting response, sustained attention, attention termination) were interrelated with respect to recognition performance. The results again confirmed that long-looking infants did not perform as well as their short-looking counterparts but further demonstrated that the phases of attention, both sustained attention and attention termination, were positively correlated with look duration (orienting response was unrelated under all examinations). This finding is interesting in that as look duration increased so did the amount of time spent in both SA and AT, therefore long-looking infants actually spent more time in SA than the short-looking infants yet this did nothing to enhance their performance. Additionally, logistic regression analyses determined that the amount of AT mediated the relationship between look duration and recognition performance. Therefore, while SA was correlated with performance, it was the amount of time spent in AT that appeared to distinguish group performance. This is suggestive that shifting and disengaging attention among visual displays (or among display features) contributes to infant recognition performance on paired-comparison tasks.

In fact, the developmental course of infant visual attention and the resulting interpretations from this work have been drawn almost exclusively from the utilization of visual displays. This challenges the generality of what is known about infants' attentional abilities across modalities. So far, there has been one study that has directly addressed the development of infants' look duration to visual/auditory displays. In an infant-controlled habituation task (Horowitz, Paden, Bhana, & Self, 1972), Shaddy and Colombo (2004) tested 4- and 6-month-olds with three display categories: dynamic audio-visual (DAV), dynamic visual (DV), and static visual (SV). Each category had two sets where a woman either read a passage from Dr. Seuss or spoke to an infant (in an infant-directed manner). Both the DV and SV were adapted from the dynamic audio-visual recording, so as the DV consisted of an articulating face with the sound muted and the SV consisted of still shots from the video clip (with the sound muted). Results of this study found that: 1) infants at both ages looked longest to the dynamic audio-visual display and least to the static, muted display, 2) look duration declined with age across all events, 3) the amount of time spent in sustained attention in 4-month-olds, but not at 6-months, was predictive of stimulus discrimination. Importantly, this study demonstrates that attention patterns to multimodal events are different than to unimodal events.

Thus, there is a need to bridge together multiple areas of research if there is to be a more comprehensive understanding of attentional development. In their everyday world, infants pay attention to a variety of events; many being multimodally specified. Thus, it is important to explore aspects of attention that are specific to certain modalities, compare attentional abilities across modalities, as well as investigate attention to events which require sensory system integration. Given the progress that has been made in studying the development of infants' visual attention, the exploration of attention in the auditory modality is of specific interest.

Attention to Auditory Events

Within the auditory modality there has been much work investigating infants' listening preferences. For example, it has been well established within the field of infant speech perception that infants show greater attention to Infant-Directed speech (IDS) over Adult-Directed speech (ADS) (Cooper & Aslin, 1990; Fernald, 1991; Papousek, Bornstein, Nuzzo, Papousek, & Symmes, 1990; Pegg, Werker, & McLeod, 1992; Werker

& McLeod, 1989). In addition to capturing and maintaining infants' attention, IDS and its corresponding characteristics; higher or exaggerated vowel pitch, greater pitch variability, slower rate/tempo, shorter utterances, longer pauses between utterances, and hyperarticulation of vowels (Burnham, Kitamura, & Vollmer-Conna, 2002; Fernald & Mazzie, 1991; Fernald & Simon, 1984; Jacobson, Boersma, Fields, & Olson, 1983; Masataka, 1992, 1996; Papousek, Papousek, & Symmes, 1991) have been shown to impact infants' responding in other important ways, it helps them regulate their emotional arousal and gain information about the communicative affect of the speaker (Fernald, 1984; Kitamura & Burnham, 1998; Singh, Morgan & Best, 2002; Stern, Spieker, & MacKain, 1982; Trainor, Austin, & Desjardins, 2000).

In addition to speech, infants pay attention to a variety of other auditory events; melodies (Trehub & Trainor, 1993), the tempo and timbre of music (Trainor, Wu & Tsang, 2004; Schellenberg, 2003), and tones (Olsho, Schoon, Sakai, Turpin, & Sperduto, 1982a, 1982b). While there has been much work investigating auditory discrimination and speech preferences, it is not yet well understood the process by which they acquire auditory information. By incorporating infants' auditory attentional abilities with our understanding of infants' visual attention, a more comprehensive picture of the development of attention can be obtained.

Advancement to the Field of Infant Attention

Even though there is not a complete understanding of the sources of variability in visual attention, there is much less known about potential differences that are observable within other modalities. Because attention involves other sensory systems and is not limited to visual processing, it becomes necessary to explore any existing differences within other modalities to gain a more comprehensive understanding of infants' attentional capacities. Further, if there are systematic differences observable within other modalities, performance comparisons can be made that will provide additional insight into the organization of infants' attention systems. As mentioned earlier, this study seeks to expand our understanding of infants' attention to events occurring within the auditory modality.

Purposes and Hypotheses

There are three purposes for this study; 1) explore whether individual differences emerge in an auditory recognition task similar to those found in the visual recognition phase of the paired-comparison task, 2) to examine recognition on a well established visual task with recognition on a similar auditory task, and 3) to identify any underlying psychophysiological mechanism that may distinguish group differences in performance on an auditory task. In order to address these issues, 4- and 8-month-old infants will be tested in an infant-controlled task that requires them to recognize a familiar event based upon a limited amount of exposure time. This task was designed to be as similar as possible across the different task modalities in order to allow for comparisons in recognition memory. The same hypotheses are predicted for infants at each age group.

Visual Task.

Hypothesis 1: There will be a significant classification x trial interaction whereas infants who are classified (based upon the length of their longest look in the classification phase) as short-looking will demonstrate a novelty preference on the recognition trials (longer looking to the novel event compared to the familiar event). Infants classified as long-looking will look equally long to both events. It is also predicted that there will be a

positive correlation between the longest look in the classification phase compared with the longest look in the familiarization phase.

Hypothesis 2: There will be significantly higher HR in the pre-attention termination phase for the long-looking infants compared to the short-looking infants (the average HR during each attentional phase will be analyzed with reference to the longest look during the classification phase). Differences in this attentional phase will account for the differences in group performance on the recognition trials. This hypothesis is consistent with the theory that the groups differ in their ability to disengage their attention. There are no specific predictions made with regard to group differences in the sustained attention phase.

Auditory Task.

Hypothesis 3: Similar to visual performance, there will be a significant classification x trial interaction whereas infants who were classified (based upon the duration of the longest listening trial during the classification phase) as short-listeners (i.e. have brief listening durations) will demonstrate a novelty preference on the recognition trials (longer listening to the novel event compared to the familiar event). Long-listening infants (long listening durations) will listen equally to both events. Additionally, it is predicted that there will be a positive correlation between the longest listening trial in the classification phase compared with the longest listening trial in the familiarization phase.

Hypothesis 4: There will be significantly higher HR in the pre-attention termination phase for the long-listening infants compared to the short-listening infants (the average HR during each attentional phase will be analyzed with reference to the longest trial during the classification phase). Differences in this attentional phase will account for the differences in group performance on the recognition trials. This hypothesis is consistent with the theory that the groups differ in their ability to disengage their attention. There are no specific predictions made with regard to group differences in the sustained attention phase.

Task Comparisons.

Hypothesis 5: Infant classifications are expected to be positively correlated across the two tasks. Therefore, infants who are classified as short-lookers will also be classified as short-listeners and infants who are classified as long-lookers will also be classified as long-listeners.

Chapter 2

Method

Participants

Thirty three 4-month-old infants and 37 8-month-old infants were recruited from the developmental science database that is jointly maintained by faculty in the Department of Psychology. The parents of the infants first received an invitation letter (see Appendix A) and then a follow-up phone call. Infants were tested within a week (before or after) of their 4-month or 8-month birth date. Out of 70 infants, a total of 39 infants completed testing on both tasks (although 3 of these infants did not provide HR data). There were 20 4-month-old infants who completed testing. An additional 13 4-month-olds were tested but were not included in the final analysis due to only completing one task (9), excessive crying (1), out of camera range for coding (2), and equipment failure (1). Nineteen, 8-month-olds completed the study. An additional 18 8-month-olds were tested but were not included in the final analysis due to only completing one task (7) excessive crying (5), disinterest (5), and equipment failure (1). None of the infants in the final sample contributed data in both age groups. Across ages, data from parental report indicated that the final sample comprised infants primarily from Caucasian-American, middle class, college educated families, and none of the infants tested had any history of prenatal or postnatal complications and were in good health (via parental report) at the time of the testing.

Apparatus

Infants were seated on their parent's lap in front of a black panel (5'8" tall x 3'9" wide) containing a 17" flat screen computer monitor (Hitachi, CML200UXW), two speakers (Sony model, SRS-88PC), and a web camcorder (Logitech, Quickcam) placed 6 inches above the monitor. The web camcorder projected the infants onto the observer computer (Dell Pentium computer; Model: DHM) located in an adjacent room, which the observer used to judge the infants' looking behavior and subsequently control the session. All sessions were recorded for later assessment of inter-rater reliability. The parent holding the infant was asked to remain silent and hold the infant as still as possible, to prevent interfering with the test design.

A Dell Pentium computer (Model: DHM) administered the custom software program for the infant-controlled, testing procedure. The computer controlled the presentation of the events, recorded the length of each trial and also concurrently sent a pulsed tone to event-mark the heart rate record (for trial onset and offset). The sound level for all auditory events was held constant across infants and was presented between 65-70 decibels (A scale).

For the recording of heart rate, Ag-AgCl disposable electrodes (Unitrace, UMP3-B) were attached to the infant's chest in a triangular array with two active leads being placed high upon each side of the sternum and the ground electrode being placed on the lower left area of the rib cage (Berg, 1972). The leads were connected to an isolated bioelectric amplifier (James Long Company model, RPC-01/04 BN) which fed into the A/D Interface and then into a 12-bit data acquisition system (IO Tech, Daqbook/112) connected to a Pentium 3 computer. Beat-to-beat heart periods, defined as the interval between successive R-waves in the ECG, were sampled at a rate of 1 kHz (Richards, 2001).

Before HR analyses were conducted, the beat to beat HR records were visually scanned in order to remove any segment(s) during which the signal became undetectable (artifact) and/or any beats which were not marked by the algorithm. In the latter case, if possible, manual marks were inserted. Each trial was then subdivided into the following successive epochs for analysis: 0 to 3 s, 3 to 9 s, and the last 1 s of the trial. The epoch sizes were chosen to yield data that were sensitive to transient changes in HR (Richards & Casey, 1992) with the first defined epoch corresponding to event orienting (0 – 3 s), the second corresponding to sustained attention (3 – 9 s) and the last epoch corresponding to attention termination (last 1 s of the trial). The mean interbeat intervals (IBIs or heart period defined as the average times between successive R waves) were calculated within each epoch by custom software (provided by the James Long Company). If any data for a given epoch was missing (i.e. HR was lost due to artifact), the overall mean for that epoch was inserted as the missing value. Because heart period (HP) is the inverse of heart rate, *decreases* in HR are depicted as *higher* IBI levels (longer periods of time between successive beats). All analyses were conducted on average IBIs in msec.

Procedure

Upon arrival, parents were given two informed consent forms (1 for them to keep and 1 for our records; see Appendix B) as well as a family demographics questionnaire (see Appendix C). Once the experimenter assessed that the infant was in a quiet and alert state, the electrodes were placed on the infant's chest and the lights were dimmed. There was one trained observer who stayed in the testing room with the parent and infant (standing behind and out of the view of the infant) and two other observers who were located in an adjacent room controlling the session. Each infant was tested in a visual and auditory task, both consisting of a classification display followed by a familiarization phase and then two test trials. Infants were first tested with the visual task and then the auditory task.

Inter-observer reliabilities were calculated offline by a trained observer for 20% of the infants tested. For those sessions randomly selected for reliability coding, each trial within a session was coded two times (the original online-observer and one offline-observer) and Pearson's bivariate correlations were calculated. The average correlation between the observers' look durations were .96; significant at the .01 level (two-tailed).

Visual Task: Classification Display

When the observer coding the session judged that the infant was looking at the screen, a photograph of a woman smiling was presented for as long as the infant was visually attending to the screen. Once the infant looks away from the screen (for at least 1 sec), the display was turned off, and the screen became blank until the infant centrally fixated again. This continued until the infant accumulated 20 seconds of looking at the photograph (see Figure 4), at which time the screen went blank, marking the end of the visual classification phase.



Figure 4: Classification Photograph

Visual Task: Familiarization Phase

When the infant had visually fixated the screen for 3 consecutive seconds, the familiarization phase began with the presentation of a static visual event, consisting of an arrangement of black elements on a white background (see Figure 5). The events used for this task were modeled to closely resemble those used by Colombo in much of his previous work (Freesman, Colombo, & Coldren, 1993; Colombo, Ryther, Frick, & Gifford, 1995). The visual event remained on the screen for as long as the infant was looking or until they accumulated 20 seconds of looking. At any point during the 20 sec, if the infant looked away (for at least 1 s) the event was turned off. The visual event was turned off, until the infant looked back toward the screen, in order to keep the design of the familiarization phase as similar as possible to the design employed within the auditory task. After the infant had accumulated 20 seconds of looking, the screen went blank and the test phase immediately began.



Figure 5: Visual Events

Visual Task: Test Trials

Each infant received a total of 4 tests trials, which were presented in a fixed order. There were two possible visual events (see Figure 5). Depending upon which event the infant was familiarized (events were counterbalanced across participants), the first test trial consisted of the novel, static event. The second test trial consisted of the event presented during familiarization (familiar). Then, both events were presented again (test trial 3, novel; test trial 4, familiar). During the test phase, the event presentation was under the infant's control. That is, they were able to look at each event for as long as they chose to do so. It was only when they disengaged and looked away from the screen (for at least 1 s) that the trial ended. Upon completion of the 4 test trials, the auditory task began.

Auditory Task: Classification Event

The classification event for the auditory task consisted of an illuminated screen and the presentation of infant-directed speech. The illuminated screen was completely white with a very small black rectangle in the center (rectangle measured 1 cm wide x 5 mm high). The same illuminated screen was used for all auditory event presentations (within and across phases of the auditory task). To begin studying auditory attention, infant-directed speech was selected as an auditory event due to its established ability to recruit and maintain infant attention, particularly given that it is a phenomenon which is naturally occurring within the environment of most infants. All auditory events were presented at the same sound level (between 65-60 db SPL; A-scale).

Once the infant fixated toward the blank, white screen, a sound track consisting of a woman speaking to an infant played for as long as the infant continued to look at the screen. Once an infant has turned away from the screen, the speech recording stopped until they visual fixated toward screen again. This continued until the infant accumulated 20 seconds of listening to the event, at which time the familiarization phase immediately began.

Auditory Task: Familiarization Phase

The familiarization phase of the auditory task began when the observer judged the infant to be looking at the blank, illuminated screen. Once the infant was looking at the screen, a short melody (consisting of 9 notes lasting approximately 5 sec in duration) was repeatedly presented until the infant had acquired 20 seconds of accumulated listening to the event. If an infant turned away from the screen, prior to accumulating 20 seconds of listening, the auditory event was turned off until the infant visually fixated the screen again. Once the infant reached the 20 second listening criterion, the familiarization phase ended and the first test trial began immediately.

Auditory Task: Test Trials

As in the visual task, each infant received a total of 4 tests trials, which were presented in a fixed order. There were two possible melodies. Depending upon which event the infant was familiarized (events were counterbalanced across participants), the first test trial consisted of the blank screen with the novel melody. The second test trial consisted of the melody presented during familiarization (familiar). Then, both events were presented again (test trial 3, novel; test trial 4, familiar). During the test phase, the event presentation was under the infant's control. That is, they were able to listen to each event for as long as they chose to do so. It was only when they disengaged and looked away from the screen (for at least 1 s) that the trial ended.

Chapter 3

Results

For infants in both age groups, only data from those who successfully completed both tasks were included in the final analyses. While there were many more infants tested (see above), this allowed for accurate comparisons of performance across tasks.

4-Month-Olds

Visual Task.

In order to assess the consistency of group classification, the peak look during the classification phase and the peak look during the familiarization phase were compared. This correlation was not statistically significant, $r(20) = -.08$, $p > .05$. Infants' peak look during the classification phase (look to the female face) averaged 16.92 s ($SD = 4.12$ s). The peak look during the familiarization phase was 15.67 s ($SD = 6.01$ s). These looks were not significantly different from one another, $t(19) = .73$, $p > .05$.

Infants were split into two groups based upon their peak look during the classification phase. There were 10 short-looking infants whose peak look was less than the median (19.75 s) and there were 10 long-looking infants whose peak look was above the median (see Table 1). A 2 x 2 ANOVA was conducted with group (short, long) as the between-subjects variable and event (novel test, familiar test) as the within-subjects variable. There was not a significant main effect for event, $F(1, 18) = 1.08$, $p > .05$, and contrary to what was predicted, there was not a significant event x group interaction $F(1, 18) = .00$, $p > .05$. Although this interaction was not significant, infants tended to look longer to the novel event (visual recognition memory) irrespective of their group classification; short-looking infants ($M_{novel} = 16.47$ s, $SD = 9.88$ s; $M_{familiar} = 12.78$ s, $SD = 9.83$ s) and long-looking infants ($M_{novel} = 21.70$ s, $SD = 24.76$ s; $M_{familiar} = 18.59$ s, $SD = 25.00$ s).

Infants' Looking and Listening Patterns

<u>Participant</u>	<u>Peak Look</u> (seconds)	<u>Classification</u> 1= Short 2= Long	<u>Mean Novel</u>	<u>Mean Familiar</u>	<u>Novelty Score</u>
617	9.12	1	20.45	8.17	0.71
33	10.23	1	15.41	4.7	0.77
623	11.00	1	15.08	8.06	0.65
611	11.70	1	28.01	16.84	0.62
21	12.10	1	10.86	13.52	0.45
606	13.20	1	36.91	38.69	0.49
18	14.00	1	5.04	8.42	0.37
37	18.10	1	16.51	5.45	0.75
586	19.51	1	10.85	11.64	0.48
598	19.51	1	5.68	12.41	0.31
20	20.00	2	11.48	11.79	0.49
42	20.00	2	16.25	6.73	0.71
43	20.00	2	7.29	4.41	0.62
53	20.00	2	7.91	6.64	0.54
583	20.00	2	67.16	15.55	0.81
585	20.00	2	68.84	82.72	0.45
601	20.00	2	7.14	7.33	0.49
602	20.00	2	5.47	5.16	0.51
604	20.00	2	7.05	5.02	0.58
628	20.00	2	18.46	40.58	0.31

Table 1: Visual Task: Individual Infant Data at 4-Months of Age

To determine if the HR measure could identify differential attention to the novel event (indicative of recognition memory) as a function of group classification, a 2 x 2 x 3 ANOVA was conducted with classification group (short, long) as the between-subjects variable and event (novel, familiar) and HR phase (OR, SA, AT) as the within-subjects variables. This analysis revealed a significant main effect for HR phase, $F(2,16) = 5.20$; $p < .05$, and a significant phase x event interaction, $F(2,16) = 3.61$; $p < .05$ (see Figure 6). In response to the novel event, infants showed slower heart rate in the OR phase ($M = 422.25$, $SD = 37.96$) compared to the SA ($M = 413.22$, $SD = 28.14$) and AT phases ($M = 409.35$, $SD = 25.03$). In response to the familiar event, infants showed slower heart rate in the OR ($M = 419.48$, $SD = 35.30$) and SA phases ($M = 417.48$, $SD = 28.09$) compared to the AT phase ($M = 404.74$, $SD = 26.02$). There were no other significant main effects or interactions, all $ps > .05$.

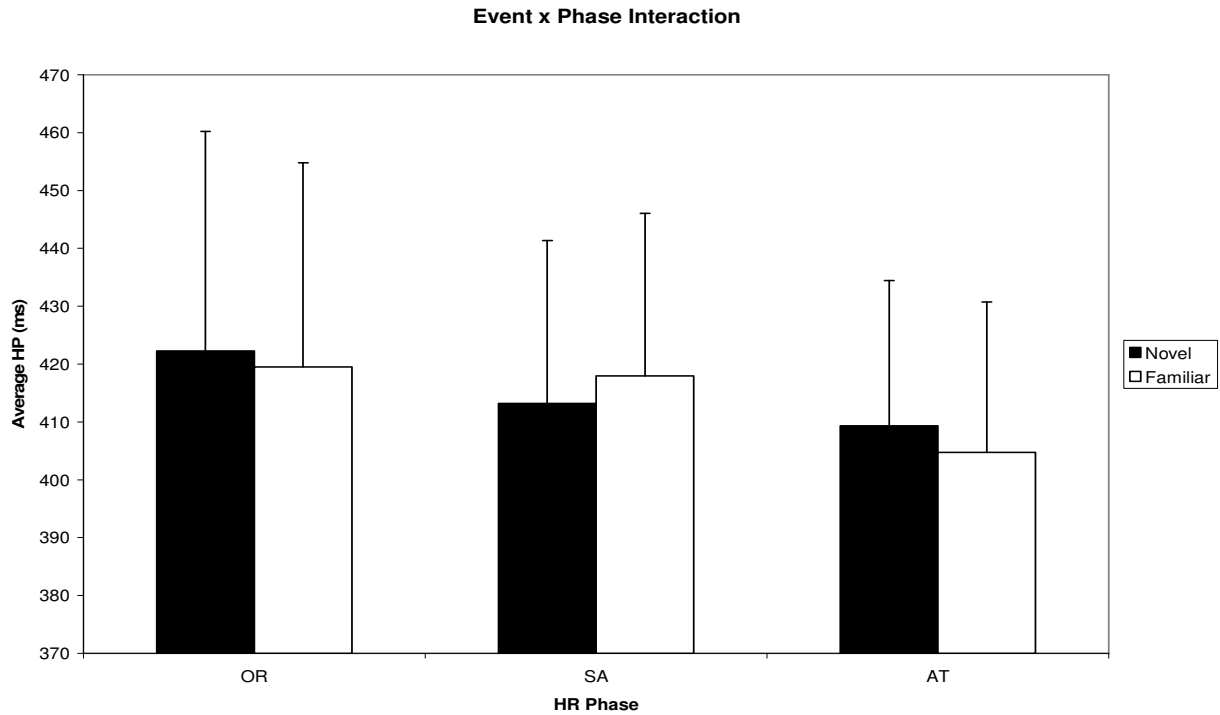


Figure 6: Visual Task: Significant Phase x Event Interaction (4mos)

It was also expected that short- and long-looking infants would show different heart rate patterns of attentional processing. To better address a difference in their information processing abilities, the HR during the peak look of visual classification was used for this analysis. More specifically, it was predicted that long-looking infants would show significantly higher heart rate in the AT phase compared to their short-looking counterparts. A 2 x 3 ANOVA was conducted with classification group (short, long) as the between-subjects variable and HR phase (OR, SA, AT) as the within-subjects variable. There was not a significant main effect for HR phase, $F(2,16) = 2.64$; $p > .05$, but there was a significant phase x group interaction, $F(2,16) = 6.60$; $p < .05$ (see Figure 7). Follow-up t-tests showed no differences as a function of group classification in any of the HR phases of attention, all p s $> .05$; OR phase ($M_{short} = 420.73$, $SD = 35.50$, $M_{long} = 439.95$, $SD = 35.10$; $t(17) = -1.18$), SA phase ($M_{short} = 432.35$, $SD = 34.77$, $M_{long} = 426.24$, $SD = 32.93$; $t(17) = .39$), AT phase ($M_{short} = 404.55$, $SD = 20.52$, $M_{long} = 426.92$, $SD = 39.19$; $t(17) = -1.53$). Given the observed variance in the AT phase, an ANOVA confirmed that there was a significant difference on the variances between these two groups, $F(1, 17) = 5.24$, $p < .05$.

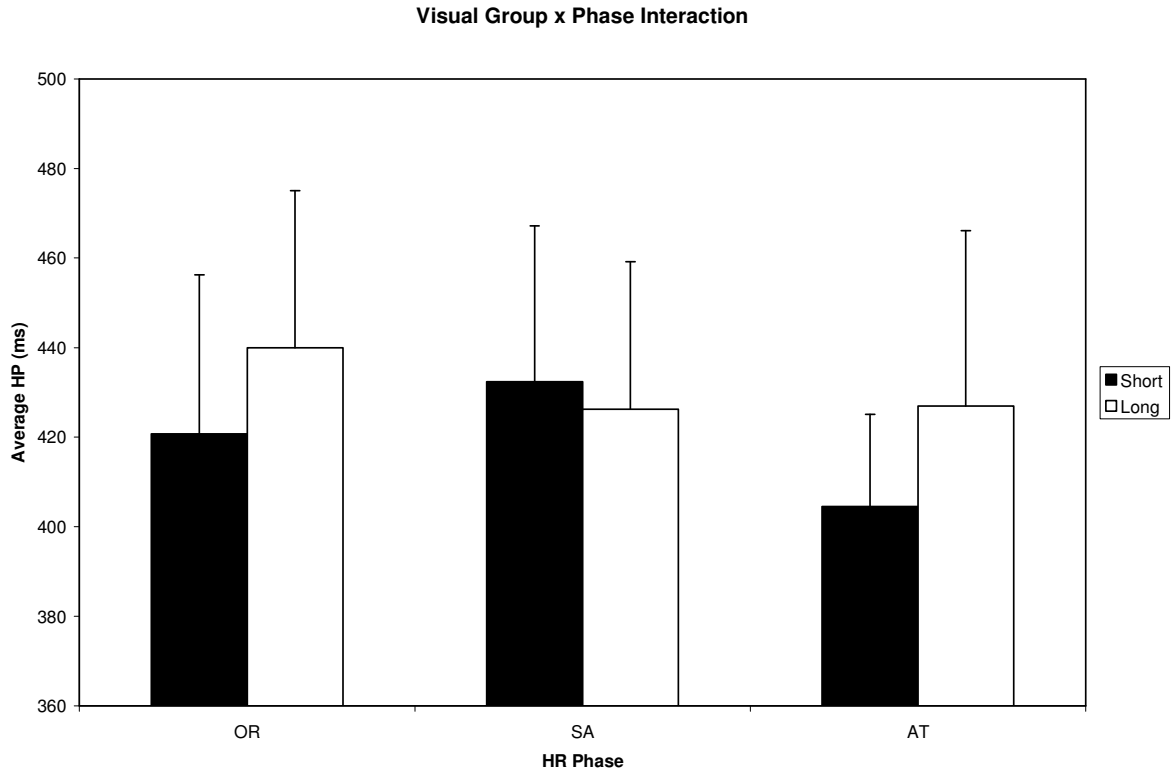


Figure 7: Visual Task: Significant Phase x Group Interaction (4mos)

In order to understand the consistency of infants' attentional patterns, correlations were conducted on the average heart rate occurring across the OR, SA, and AT phases. All three phases were significantly correlated with each other, all p s < .01 (see Table 2). To determine if there was a correspondence between each HR attention phase and an infant's peak look, correlations were conducted on infants' longest look during classification and their average heart rate during OR, SA, and AT. There were no significant correlations between the duration of the peak look and any of the three HR phases; OR $r(19) = .38, p > .05$, SA $r(19) = -.38, p > .05$; AT $r(19) = .28, p > .05$. Finally, correlations were conducted to determine whether the three HR phases were correlated across the classification and familiarization periods of the experimental protocol (heart rate values were taken from the peak look during each phase). All three phases were correlated from classification to familiarization; OR $r(19) = .83, p < .01$, SA $r(19) = .72, p < .01$; AT $r(19) = .63, p < .01$.

HR Phase	Sustained Attention	Attention Termination
<i>(n = 19)</i>		
Orienting Response	0.82	0.69
Sustained Attention		0.6

Table 2: Visual Task: Correlations of HR Phases (4mos)

Auditory Task.

In order to assess the consistency of listening duration to infant-directed speech (IDS; classification phase) compared to the listening duration to a simple melody (familiarization), the longest listening trial during the classification phase and the longest listening trial during the familiarization phase were compared. As previously mentioned, all auditory trials were concurrently paired with an illuminated screen; therefore when the infant looked toward the screen the auditory track began playing. This correlation was statistically significant, $r(20) = .39$, $p < .05$. Infants' longest listening trial to IDS averaged 14.24 s ($SD = 5.05$ s). The longest listening trial during the familiarization phase was 14.33 s ($SD = 5.45$ s). These listening trials were not significantly different from one another, $t(19) = -.07$, $p > .05$.

Infants were split into two groups based upon their longest listening trial during the classification phase. There were 10 short-listening infants whose peak look was less than the median (12.66 s) and there were 10 long-listening infants whose peak look was above the median (see Table 3). A 2 x 2 ANOVA was conducted with group (short, long) as the between-subjects variable and event (novel test, familiar test) as the within-subjects variable. There was not a significant main effect for event, $F(1, 18) = .20$, $p > .05$, and contrary to what was predicted, there was not a significant event x group interaction $F(1, 18) = 2.38$, $p > .05$. Although this interaction was not significant, the long-listening infants did tend to listen longer to the novel melody (visual recognition memory); long-listening infants ($M_{novel} = 16.04$ s, $SD = 13.94$ s; $M_{familiar} = 10.29$ s, $SD = 12.08$ s) whereas short-listening infants attended longer to the familiar melody ($M_{novel} = 11.99$ s, $SD = 6.89$ s; $M_{familiar} = 15.12$ s, $SD = 13.41$ s).

<u>Participant</u>	<u>Peak Look</u> (seconds)	<u>Classification</u> 1= Short 2= Long	<u>Mean Novel</u>	<u>Mean Familiar</u>	<u>Novelty Score</u>
623	8.07	1	18.36	5.51	0.77
598	8.28	1	4.82	11.01	0.3
53	8.45	1	13.7	11	0.55
611	9.00	1	26.48	46.69	0.36
43	9.03	1	16	8.07	0.66
21	9.96	1	5.47	13.55	0.29
617	10.10	1	10.03	4.39	0.7
602	11.30	1	12.09	12.71	0.49
42	11.48	1	7.1	7.13	0.5
37	12.03	1	5.87	31.23	0.16
601	13.30	2	7.94	9.24	0.46
20	13.90	2	43.54	4.81	0.9
18	20.00	2	10.44	7.49	0.58
33	20.00	2	4.94	3.48	0.59
583	20.00	2	12.29	6.29	0.66
585	20.00	2	4.72	7.55	0.38
586	20.00	2	35.76	44.38	0.45
604	20.00	2	9.4	5.53	0.63
606	20.00	2	25.65	7.44	0.78
628	20.00	2	5.75	6.8	0.46

Table 3: Auditory Task: Individual Infant Data at 4-Months of Age

To further assess infants' recognition performance, a 2 x 2 x 3 ANOVA was conducted with classification group (short, long) as the between-subjects variable and event (novel, familiar) and HR phase (OR, SA, AT) as the within-subjects variables. This analysis revealed a significant main effect for event, $F(1,16) = 4.53$; $p < .05$, with infants showing slower heart rate to the novel melody ($M = 425.87$, $SD = 25.38$) compared to the familiar melody ($M = 418.15$, $SD = 20.54$). There was also a significant main effect for HR phase, $F(2,16) = 18.57$; $p < .05$, and a significant group x HR phase interaction, $F(2,15) = 4.63$; $p < .05$ (see Figure 8). Follow-up t-tests showed that short-listening infants displayed significantly slower heart rate during SA ($M = 437.84$, $SD = 31.88$) compared to OR ($M = 406.58$, $SD = 24.64$; $t(8) = -4.61$; $p < .05$) and compared to AT ($M = 412.51$, $SD = 26.70$; $t(8) = 4.11$; $p < .05$), whereas, long-listening infants only showed significantly slower heart rate during SA ($M = 430.60$, $SD = 15.78$) compared to OR ($M = 425.15$, $SD = 34.61$; $t(8) = -5.14$; $p < .05$). Long-listening infants' average heart rate during the AT phase ($M = 425.15$, $SD = 34.61$) was not significantly different from their OR or SA, both $ps > .05$. Across groups, there were no significant differences in any of the HR phases; OR $t(16) = -1.37$; $p > .05$; SA $t(16) = .61$; $p < .05$; AT $t(16) = -.86$; $p > .05$, but an ANOVA on the variance for the SA phase showed a significant difference between groups, $F(1,16) = 10.52$; $p < .05$. Additionally, there were no other significant interactions, all $ps > .05$; event x class, $F(1,16) = 1.75$; event x phase, $F(2,15) = 1.29$; event x phase x class, $F(2,15) = .14$.

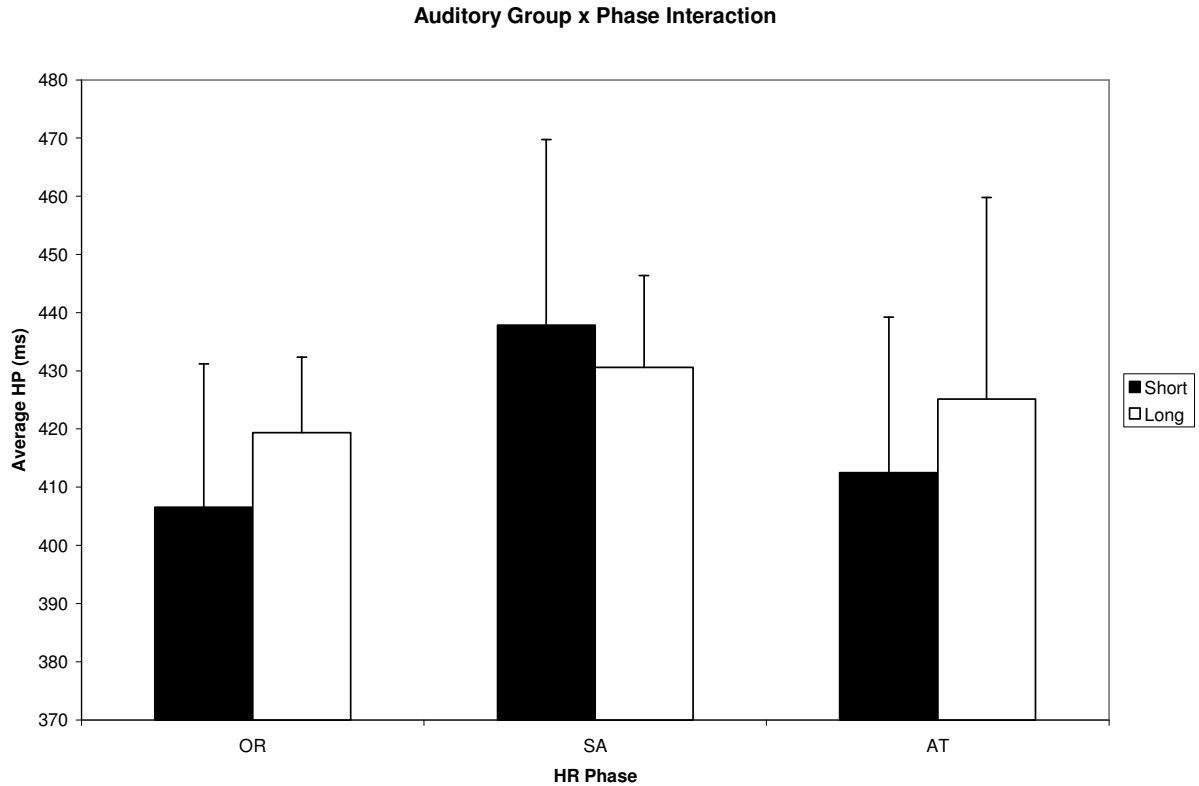


Figure 8: Auditory Task: Significant Phase x Group Interaction (4mos)

It was also expected that there would be HR differences in attentional phases as function of group classification. More specifically, it was predicted that short-listening infants would show significantly higher HR in the AT phase compared to the long-listening group. The HR phases for this analysis corresponded to the peak listening trial during the classification phase. A 2 x 3 ANOVA was conducted with classification group (short, long) as the between-subjects variable and HR phase (OR, SA, AT) as the within-subjects variable. There was a significant main effect for HR phase, $F(2,15) = 6.85$; $p < .05$, with the average heart rate during SA being significantly slower ($M = 435.30$, $SD = 24.31$) than OR ($M = 419.67$, $SD = 29.20$) and AT ($M = 417.69$, $SD = 34.47$). There was not a significant phase x group interaction, $F(2,15) = .65$; $p > .05$.

In order to understand the consistency of infants' attentional patterns, correlations were conducted on the average heart rate occurring across the OR, SA, and AT phases. All three phases were significantly correlated with each other, all $ps < .01$ (see Table 4). To determine whether individual differences in the three HR phases (OR, SA, AT) were correlated across the classification period, correlations were conducted on the peak listening trial during the classification phase and each HR attentional phase. There were no significant correlations between the duration of the peak trial and any of the three HR phases; OR $r(18) = -.18$, $p > .05$, SA $r(18) = .04$, $p > .05$; AT $r(18) = -.02$, $p > .05$. Finally, correlations were conducted to determine whether the three HR phases were correlated across the classification and familiarization periods of the experimental protocol (heart rate values were taken from the peak listening trial during each phase).

All three phases were correlated from classification to familiarization; OR $r(18) = .71, p < .01$, SA $r(18) = .91, p < .01$; AT $r(18) = .80, p < .01$.

HR Phase	Sustained Attention	Attention Termination
(n = 19)		
Orienting Response	0.74	0.87
Sustained Attention		0.8

Table 4: Auditory Task: Correlations of HR Phases (4mos)

Task Comparisons.

The primary purpose of this investigation was to compare infants' performance on a visual recognition memory task with their performance on an auditory recognition memory task. There was one specific prediction; group classifications would be positively correlated across the two tasks (i.e. short-lookers would also be short-listeners, long-lookers would also be long-listeners). This prediction was not supported, as there was no association between infants' visual classification and their auditory classification, $r(20) = .20, p > .05$. Additionally, there were no associations between the duration of an infant's peak looking trial and their peak listening trial during either the classification phase, $r(20) = .13, p > .05$, or during the familiarization phase, $r(20) = -.06, p > .05$.

Even though there was not a relationship on the classification variable across tasks, it was possible that there was an association of infants' recognition performance across tasks. To make this comparison, novelty scores were derived for each infant's performance across tasks. These scores were calculated on the test trials by taking the average amount of time spent attending to the novel event and dividing it by the total amount of time attending to both events (average novel + average familiar). Ratio scores that were $\geq .52$ were considered to be novel, .49 to .51 were considered to be equal, and scores $\leq .48$ were considered to be familiar. Surprisingly, the visual novelty scores were not significantly correlated with the auditory novelty scores, $r(20) = .18, p > .05$.

Of the 20 4-month-old infants, there were 13 who showed concordant ratio scores (i.e. visual novelty score $\geq .52$, auditory novelty score $\geq .52$ or visual novelty score was $\leq .48$, auditory novelty score was $\leq .48$; see Table 5). In this subset, the relationship between an infant's visual classification and their auditory classification was considered, but again there was not a relationship between these variables, $r(13) = .23, p > .05$. In a similar vein, of the 20 infants in the 4-month sample, there were 12 who were classified the same across tasks (i.e. short, short; long, long). Of those 12 infants, the visual novelty score and the auditory novelty scores were compared in order to further assess if there was an association of recognition memory across tasks. There was not a significant correlation, $r(12) = .23, p > .05$, for recognition memory in this subset.

<u>Participant</u>	<u>Peak Look</u> <i>Visual</i> <i>(sec)</i>	<u>Peak Look</u> <i>Auditory</i>	<u>Classification</u> <i>1= Short Looker</i> <i>2= Long Looker</i>	<u>Classification</u> <i>1=Short Listener</i> <i>2= Long Listener</i>	<u>Novelty Score</u> <i>Visual</i>	<u>Novelty Score</u> <i>Auditory</i>
18	14.00	20	1	2	0.37	0.58
20	20.00	13.9	2	2	0.49	0.9
21	12.10	9.96	1	1	0.45	0.29
33	10.23	20	1	2	0.77	0.59
37	18.10	12.03	1	1	0.75	0.16
42	20.00	11.48	2	1	0.71	0.5
43	20.00	9.03	2	1	0.62	0.66
53	20.00	8.45	2	1	0.54	0.55
583	20.00	20	2	2	0.81	0.66
585	20.00	20	2	2	0.45	0.38
586	19.51	20	1	2	0.48	0.45
598	19.51	8.28	1	1	0.31	0.3
601	20.00	13.3	2	2	0.49	0.46
602	20.00	11.3	2	1	0.51	0.49
604	20.00	20	2	2	0.58	0.63
606	13.20	20	1	2	0.49	0.78
611	11.70	9	1	1	0.62	0.36
617	9.12	10.1	1	1	0.71	0.7
623	11.00	8.07	1	1	0.65	0.77
628	20.00	20	2	2	0.31	0.46

Table 5: 4-Months: Individual Infants' Performance Across Tasks

Summary of 4-Month-Old Results.

Contrary to the predictions made in the first hypothesis, 4-month-old infants did not show evidence of visual recognition memory as a function of group classification. Short-looking infants did not demonstrate a novelty preference on the recognition trials. Also, there was not a significant correlation between the longest look in the visual classification phase and the visual familiarization phase. With respect to the second hypothesis, there were no differences in the heart rate defined phases of attention as a function of group classification. Long-looking infants did not have significantly higher heart rate in the attention termination phase compared to the short-looking infants. Auditorily, there was no evidence of recognition memory as a function of group classification (i.e. short-listening infants did not show a novelty preference on test trial) but there was a significant positive correlation between the longest listening trials in the classification phase and familiarization phase (Hypothesis 3). As in the visual task, there were no differences in the heart rate defined phases of attention as a function of group classification (Hypothesis 4). Finally, there were no significant associations of infant performance across tasks on any of the compared variables. More specifically with regard to Hypothesis 5, there was not a positive correlation amongst group classification across the two tasks.

8-month-olds

Visual Task.

In order to assess the consistency of look duration, the peak look during the classification phase and the peak look during the familiarization phase were compared. This correlation was statistically significant, $r(19) = .42$, $p < .05$. Infants' peak look during the classification phase (look to the female face) averaged 13.60 s ($SD = 5.04$ s). The peak look during the familiarization phase was 11.08 s ($SD = 5.03$ s). These looks were significantly different from one another, $t(18) = 2.03$, $p = .05$.

Infants were split into two groups based upon their peak look during the classification phase. There were 10 short-looking infants whose peak look was less than the median (13.31 s) and there were 9 long-looking infants whose peak look was above the median (see Table 6). A 2 x 2 ANOVA was conducted with group (short, long) as the between-subjects variable and event (novel test, familiar test) as the within-subjects variable. There was not a significant main effect for event, $F(1, 17) = .42$, $p > .05$, and contrary to what was predicted, there was not a significant event x group interaction $F(1, 17) = .09$, $p > .05$.

<u>Participant</u>	<u>Peak Look</u> (seconds)	<u>Classification</u> 1= Short 2= Long	<u>Mean Novel</u>	<u>Mean Familiar</u>	<u>Novelty Score</u>
45	4.92	1	4.56	5.04	0.48
587	7.25	1	4.55	8.69	0.34
30	8.39	1	11.51	5.82	0.66
47	8.92	1	7.11	6.68	0.52
25	9.10	1	8.37	20.65	0.29
13	9.14	1	10.2	4.2	0.71
28	9.21	1	10.32	5.7	0.64
613	12.30	1	4.39	7.35	0.37
15	13.30	1	6.17	8.62	0.42
49	13.31	1	5.67	4.37	0.56
32	13.40	2	4.35	8.7	0.33
3	15.03	2	10.47	12.64	0.45
22	16.90	2	5.44	4.71	0.54
12	17.40	2	10.84	12.19	0.47
6	20.00	2	5.84	8.91	0.40
29	20.00	2	11.84	5.59	0.68
44	20.00	2	9.18	6.97	0.57
48	20.00	2	11.4	22.88	0.33
589	20.00	2	7.71	4.95	0.61

Table 6: Visual Task: Individual Infant Data at 8-Months of Age

To determine if the HR measure could identify differential attention to the novel event (indicative of recognition memory) as a function of group classification, a 2 x 2 x 3 ANOVA was conducted with classification group (short, long) as the between-subjects variable and event (novel, familiar) and HR phase (OR, SA, AT) as the within-subjects variables. This analysis revealed a significant main HR phase, $F(2,15) = 10.40$; $p < .05$, a significant phase x event interaction, $F(2,15) = 3.18$; $p < .05$, and a significant event x phase x group interaction. There was not a significant main effect for event, $F(1,16) = .30$; $p > .05$, and there were other significant interactions, all $ps > .05$; event x group, $F(1,16) = .01$; phase x group, $F(2,15) = 1.33$.

In order to better understand the three-way interaction, follow up 2 x 3 within-subject ANOVAs were conducted by classification group. For the short-looking infants, there was a significant main effect for HR phase, $F(2,8) = 16.48$; $p < .05$, with slower heart rate occurring during the OR phase ($M = 462.49$, $SD = 26.07$) compared to SA ($M = 447.62$, $SD = 18.01$; $t(9) = 2.44$; $p < .05$) and to AT ($M = 442.21$, $SD = 23.05$; $t(9) = 4.97$; $p < .05$). There was not a significant main effect for event, $F(1,9) = .07$, $p > .05$, and while it was not significant, the event x phase interaction approached significance $F(1,9) = 3.84$, $p = .06$ (see Figure 9). For the long-looking infants, there was not a significant main effect for event, $F(1,7) = .45$, $p > .05$, or for phase, $F(1,7) = 1.20$, $p > .05$, and there was not a significant event x phase interaction, $F(1,7) = 1.36$, $p > .05$.

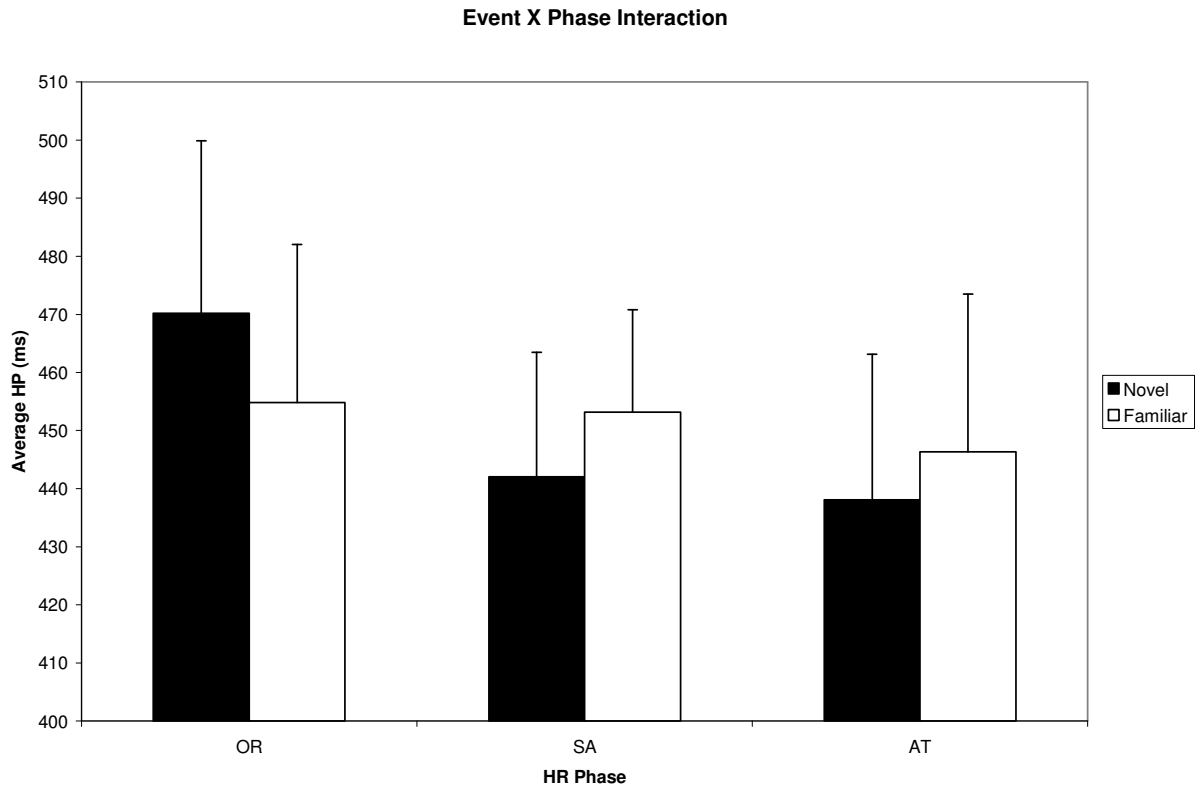


Figure 9: Visual Task: Event X Phase Interaction, $p = .06$ (8mos)

It was also expected that there would be HR differences in attentional phases as function of group classification. More specifically, it was predicted that long-looking infants would show significantly higher HR in the AT phase compared to their short-looking counterparts. The HR phases for this analysis corresponded to the peak visual look during the classification phase. A 2 x 3 ANOVA was conducted with classification group (short, long) as the between-subjects variable and HR phase (OR, SA, AT) as the within-subjects variable. There was not a significant main effect for HR phase, $F(2,15) = 1.14$; $p > .05$, nor was there a significant phase x group interaction, $F(2,15) = .67$; $p > .05$.

In order to understand the consistency of infants' attentional patterns, correlations were conducted on the average heart rate occurring across the OR, SA, and AT phases. There were significant correlations between SA and OR, $r(18) = .68$, $p < .05$, and between SA and AT, $r(18) = .69$, $p < .05$, but not between OR and AT, $r(19) = .35$, $p > .05$. To determine if there was a correspondence between each HR attention phase and an infant's peak look, correlations were conducted on infants' longest look during classification and their average heart rate during OR, SA, and AT. There were no significant correlations between the duration of the peak look and any of the three HR phases; OR $r(18) = .08$, $p > .05$, SA $r(18) = .20$, $p > .05$; AT $r(18) = .20$, $p > .05$. Finally, correlations were conducted to determine whether the three HR phases were correlated across the classification and familiarization periods of the experimental protocol (heart rate values were taken from the peak look during each phase). There was a significant correlation during OR from classification to familiarization, OR $r(18) = .48$, $p < .05$, but not during SA, $r(18) = .35$, $p > .05$, or AT, $r(18) = .29$, $p > .05$.

Auditory Task.

In order to assess the consistency of listening duration to infant-directed speech (IDS; classification phase) compared to the listening duration to a simple melody (familiarization), the longest listening trial during the classification phase and the longest listening trial during the familiarization phase were compared. This correlation was not statistically significant, $r(19) = .22$, $p > .05$. Infants' longest listening trial to IDS averaged 12.15 s ($SD = 5.02$ s). The longest listening trial during the familiarization phase was 15.66 s ($SD = 4.59$ s). These listening trials were significantly different from one another, $t(18) = -2.54$, $p < .05$.

Again, infants were split into two groups based upon their longest listening trial during the classification phase. There were 9 short-listening infants whose peak look was less than the median (10.85 s) and there were 10 long-listening infants whose peak look was above the median (see Table 7). A 2 x 2 ANOVA was conducted with group (short, long) as the between-subjects variable and event (novel test, familiar test) as the within-subjects variable. There was not a significant main effect for event, $F(1,17) = 3.06$, $p > .05$, and contrary to what was predicted, there was not a significant event x group interaction $F(1, 17) = .58$, $p > .05$.

Infants' Looking and Listening Patterns

<u>Participant</u>	<u>Peak Look</u> (seconds)	<u>Classification</u> 1= Short 2= Long	<u>Mean Novel</u>	<u>Mean Familiar</u>	<u>Novelty Score</u>
6	5.03	1	6.05	12.29	0.33
49	6.09	1	6.12	11.72	0.34
25	6.76	1	16.64	6.12	0.73
28	8.14	1	12.02	10.6	0.53
29	8.35	1	21.95	8.15	0.73
32	8.50	1	36.15	5.17	0.87
12	8.98	1	14.82	20.45	0.42
30	10.46	1	15.87	6.97	0.69
589	10.60	1	9.32	9.93	0.48
45	10.85	2	22.5	12.03	0.65
613	11.23	2	10.88	8.19	0.57
3	11.50	2	27.18	27.86	0.49
13	13.10	2	11.7	10.87	0.52
48	15.46	2	8.43	7.51	0.53
587	16.06	2	10.36	4.62	0.69
22	18.70	2	5.26	12.87	0.29
15	20.00	2	15.62	9.59	0.62
44	20.01	2	8.97	11.03	0.45
47	21.21	2	21.37	17.02	0.56

Table 7: Auditory Task: Individual Infant Data at 8-Months of Age

To further assess infants' recognition performance, a 2 x 2 x 3 ANOVA was conducted with classification group (short, long) as the between-subjects variable and event (novel, familiar) and HR phase (OR, SA, AT) as the within-subjects variables. This analysis revealed a significant main effect for HR phase, $F(2,15) = 15.86$; $p < .05$, with each HR phase being significantly different; SA > OR $t(18) = -5.95$, $p < .05$, SA > AT $t(18) = 2.11$, $p < .05$, and AT > OR $t(18) = -2.18$, $p < .05$ (see Table 8). There was not a significant main effect for event, $F(1,16) = 1.83$; $p > .05$, and there were no other significant interactions, all $ps > .05$; event x group, $F(1,16) = .70$; phase x group, $F(2,15) = .21$; event x phase, $F(2,15) = .64$; event x phase x group, $F(2,15) = .16$.

HR Phase (<i>n</i> = 18)	Mean Heart Period (ms)	Standard Deviation
Orienting Response	443.68	31.27
Sustained Attention	470.57	31.49
Attention Termination	457.9	29.18

Table 8: Auditory Task: Significant Main Effect for Heart Rate Phase (8mos)

It was also expected that there would be HR differences in attentional phases as function of group classification. More specifically, it was predicted that short-listening infants would show significantly higher HR in the AT phase compared to the long-listening group. The HR phases for this analysis corresponded to the peak listening trial during the classification phase. A 2 x 3 ANOVA was conducted with classification group (short, long) as the between-subjects variable and HR phase (OR, SA, AT) as the within-subjects variable. There was a significant main effect for HR phase, $F(2,15) = 7.91$; $p < .05$, with the average heart rate during SA being significantly slower ($M = 489.26$, $SD = 42.94$) than AT ($M = 461.33$, $SD = 25.89$; see Table 9). There was not a significant phase x group interaction, $F(2,15) = .63$; $p > .05$.

HR Phase (<i>n</i> = 18)	Mean Heart Period (ms)	Standard Deviation
Orienting Response	477.69	51.27
Sustained Attention	489.26	42.94
Attention Termination	461.33	25.89

Table 9: Auditory Task: Significant Main Effect for Heart Rate Phase in Classification (8mos)

In order to understand the consistency of infants' attentional patterns, correlations were conducted on the average heart rate occurring across the OR, SA, and AT phases. All three phases were significantly correlated with each other, all $ps < .01$ (see Table 10). To determine whether individual differences in the three HR phases (OR, SA, AT) were correlated across the classification period, correlations were conducted on the peak listening trial during the classification phase and each HR attentional phase. There were no significant correlations between the duration of the peak trial and any of the three HR phases; OR $r(18) = -.08$, $p > .05$, SA $r(18) = -.02$, $p > .05$; AT $r(18) = -.12$, $p > .05$. Finally, correlations were conducted to determine whether the three HR phases were correlated across the classification and familiarization periods of the experimental protocol (heart rate values were taken from the peak listening trial during each phase). All three phases were correlated from classification to familiarization; OR $r(18) = .70$, $p < .01$, SA $r(18) = .54$, $p < .05$; AT $r(18) = .59$, $p < .01$.

HR Phase	Sustained Attention	Attention Termination
(n = 18)		
Orienting Response	0.85	0.73
Sustained Attention		0.72

Table 10: Auditory Task: Correlations of HR Phases (4mos)

Task Comparisons.

Eight-month-olds' performance on the visual recognition memory task was compared with their performance on the auditory recognition memory task. Again, it was predicted that classifications would be positively correlated across the two tasks (i.e. short-lookers would also be short-listeners, long-lookers would also be long-listeners). This prediction was not supported, as there was no association between infants' visual classification and their auditory classification, $r(18) = -.22, p >.05$. Additionally, there were no associations between the duration of an infant's peak looking trial and their peak listening trial during either the classification phase, $r(18) = -.01, p >.05$, or during the familiarization phase, $r(18) = -.34, p >.05$.

Even though there was not a relationship on the classification variable across tasks, it was possible that there was an association of infants' recognition performance across tasks. As with the 4-month-olds, the visual novelty scores were not significantly correlated with the auditory novelty scores, $r(18) = -.23, p >.05$.

Of the 18 infants, there were 7 who showed concordant ratio scores (i.e. visual novelty score $>.52$, auditory novelty score $>.52$ or visual novelty score was $<.48$, auditory novelty score was $<.48$; see Table 11). In this subset, the relationship between an infant's visual classification and their auditory classification was considered, but again there was not a relationship between these variables, $r(7) = -.54, p >.05$. In a similar vein, of the 18 infants in the 8-month sample, there were 7 who were classified the same across tasks (i.e. short, short; long, long). Of those infants, the visual novelty score and the auditory novelty scores were compared in order to further assess if there was an association of recognition memory across tasks. There was not a significant correlation, $r(7) = -.27, p >.05$, for recognition memory in this subset.

<u>Participant</u>	<u>Peak Look</u> <i>Visual</i> <i>(sec)</i>	<u>Peak Look</u> <i>Auditory</i>	<u>Classification</u> <i>1= Short</i> <i>Looker</i> <i>2= Long</i> <i>Looker</i>	<u>Classification</u> <i>1=Short</i> <i>Listener</i> <i>2= Long</i> <i>Listener</i>	<u>Novelty Score</u> <i>Visual</i>	<u>Novelty Score</u> <i>Auditory</i>
6	20.00	5.03	2	1	0.4	0.33
12	17.40	8.98	2	1	0.47	0.42
13	9.14	13.1	1	2	0.71	0.52
15	13.30	20	1	2	0.42	0.62
22	16.90	18.7	2	2	0.54	0.29
25	9.10	6.76	1	1	0.29	0.73
28	9.21	8.14	1	1	0.64	0.53
29	20.00	8.35	2	1	0.68	0.73
30	8.39	10.46	1	1	0.66	0.69
32	13.40	8.5	2	1	0.33	0.87
44	20.00	20.01	2	2	0.57	0.45
45	4.92	10.85	1	2	0.48	0.65
47	8.92	21.21	1	2	0.52	0.56
48	20.00	15.46	2	2	0.33	0.53
49	13.31	6.09	1	1	0.56	0.34
587	7.25	16.06	1	2	0.34	0.69
589	20.00	10.6	2	1	0.61	0.48
613	12.30	11.23	1	2	0.37	0.57

Table 11: Performance Comparisons by Age (8mos)

Summary of 8-Month-Old Results.

With regard to the first hypothesis, 8-month-old infants did not show evidence of visual recognition memory as a function of group classification. Short-looking infants did not demonstrate a novelty preference on the recognition trials. However, there was a significant correlation between the longest look in the visual classification phase and the visual familiarization phase. The second hypothesis predicted that there would be differences in the heart rate defined phases of attention as a function of group classification. This was not supported as long-looking infants did not have significantly higher heart rate in the attention termination phase compared to the short-looking infants. In the auditory task, again, there was no evidence of recognition memory as a function of group classification (i.e. short-listening infants did not show a novelty preference on test trial) and there was not a significant correlation between the longest listening trial in the classification phase compared to the familiarization phase (Hypothesis 3). As in the visual task, there were no differences in the heart rate defined phases of attention as a function of group classification (Hypothesis 4). Finally, there were no significant associations of infant performance across tasks on any of the compared variables. More specifically with regard to Hypothesis 5, there was not a positive correlation amongst group classification across the two tasks.

Chapter 4

Discussion & Conclusions

The primary purpose of this project was to explore the patterns of infants' visual processing abilities with their auditory processing abilities. Within the infant attention literature, it has been shown that there are two predominant patterns of attentional processing; short-looking infants who process visual information quickly and efficiently and long-looking infants who require more time to process an event. Because this pattern has only been examined within the visual domain, the way in which infants process and attend to information in other sensory systems is not well understood. More specifically, this project first sought to establish two patterns of infants' auditory attention and compare their task performance of recognition memory for a familiarized event. Additionally, the patterns of infants' attention to a visual and auditory event were compared to examine the concordance of processing abilities across modalities. There are a number of findings which need to be separately addressed in the sections that follow.

Lack of Replication in the 4 Month-Old Visual Task

In this study, 4-month-old infants classified as short-lookers were expected to recognize the familiar event after 20 s of exposure in the familiarization period. It was expected that these infants would look significantly longer on the test trials to the novel event compared to the familiar (see Colombo, 2004 for a review). It was surprising that this was not replicated within our lab. However, there maybe several differences to note between the studies which could account for the lack of visual recognition. Foremost, at this age there was a sample size of 20 infants. In all other work within this field, the smallest sample size was 40. More often, this work is found to report sample sizes of at least 50 infants. This is an important consideration for this study as it would be difficult to detect an effect (in either the behavioral or psychophysiological data) when the statistical power is low. Importantly, there are other methodological differences as well.

In all of the other recognition memory tasks, a paired-comparison task was used to assess recognition memory. In this way, classification and familiarization periods are the same as in this study, but on the test trials, events are presented side by side. This forces an infant to choose an event on which to fixate. The infants are always able to look at the event as long as they choose to do so, however they must fixate to each event for 5 s. In this study, the test trials were presented separately. Therefore, after exposure during the familiarization period, the novel event was presented in isolation until the infant disengaged and looked away from the screen. The next trial consisted of the familiar event presented in isolation (until the infant disengaged). Each infant was given four test trials (2 of each event; novel/familiar). While these designs do differ, there is theoretical support from work with infant habituation studies that would suggest that recognition (or recover to novelty) would still be manifested. Habituation paradigms vary in design depending upon whether there are a fixed number of trials (by the experimenter) or the trials are infant-controlled (dependent upon an individual infant's time to habituate). In either case, at the onset of an event if infants discriminate a change from that which they were just exposed, they will show an increase in attention. If they fail to discriminate a change, looking time remains short as the event is perceived as the same as that which they just attended. This design was more similar to that of habituation but the exposure

time remained similar to those that had been employed in the paired-comparison tasks. It was still expected that if infants recognized the novel event as being different from the familiar, they would show differential patterns of looking during the test trials. This is reasonable, since the exposure time (20 s) established two groups of infants and produced differences in recognition performance.

This design has two implications for testing infants' recognition memory, as it could be argued that it is a more challenging task than the paired-comparison. First, this design requires an infant to maintain a representation of the familiar event, process the new event and recognize that it is different from the familiar one. In the paired-comparison, an infant does not have to maintain the representation of the familiar event, because it is simultaneously being presented. This allows them to *compare* the events and choose to attend to the novel one. Therefore, an infant does not have to recall the familiar event in order to make a comparison on the test trials. In addition to this memory load, this task is also challenging given that it is entirely dependent upon an infant looking at the screen for the event to be displayed. To clarify, the event was only presented after an infant had looked at the screen for 3 consecutive seconds. Therefore inherently, there was a 3 s delay after the familiarization phase before the novel event was available for viewing. This delay was consistent in all phase of the task and was built in to ensure that the infants' HR had a chance to return to baseline level before the onset of a given event. This delay in and of itself, could have hindered recognition performance. However, the time in between trials could vary quite greatly depending upon the infants' behavior. This is a more serious problem as some infants disengaged from a trial and then took several seconds before visually fixating back toward the screen. If this was a long period of time, it would not be surprising that infants failed to show recognition of the event. Inter-trial intervals (ITIs) varied within the session of a given infant and also varied across individual infants. This methodological factor has implications not only on the test trials for recognition memory but also has implications for infants' abilities to encode information during the familiarization phase.

Theoretically, it is during the familiarization period that there are encoding differences amongst the long- and short-looking infants. Short-looking infants have been thought to be more quick and efficient in their abilities to encode information. Given the potential differences in the ITIs, these abilities could be compromised for both groups, but particularly for the short-lookers. In this vein, if a short-looking infant had a long ITI, it may take them a little longer to encode the same event. This could potentially increase the length of their peak look, affect the completeness of their encoding of the event in a 20 s accumulation time period, or could hinder recognition if there was a long ITI between the last trial in familiarization and the first test trial. Regardless, short-long infants' abilities to show visual recognition are potentially more at risk than the long-lookers, as theoretically they are not showing recognition with a short exposure time anyway.

Interestingly, the mean peak look duration during the classification phase in this study was 15.7 s and 14.5 s on the familiarization phase. It is important to note the criterion for group classification at 4 months of age in Colombo's work is 9 s. This could be a design factor, as his photograph is presented and the infants' fixations are subsequently recorded until the infant has acquired 20 s. Comparatively in this study, the photograph was presented when the infant fixated the screen and was then removed when

the infant disengaged their attention from it. Aside for the method of presentation, it is also possible that there was too much discrepancy amongst the actual photographs used for classification. While both photographs were of a smiling female face against a light background, the attractiveness of the woman photographed for this study could have been a confounding variable. It has been shown that infants look longer at faces that are judged by adults to be highly attractive as compared to faces that are judged by adults to be less appealing (Langlois, Ritter, Roggman & Vaughn, 1991). Therefore, it is possible that the average look duration (during classification in this study) was longer because infants found our model to have highly attractive features.

It was surprising that there was not a significant correlation between the look durations across classification and familiarization, especially as all three HR phases were correlated across experimental phase. Additionally, look duration in both phases have been found to be correlated with other work using similar events. If the perceived attractiveness of the classification photograph is of issue, it might not be surprising that these events did not correlate as the static geometric event could not have been as interesting. Given that the means were so similar however, the reason for a lack of correspondence in look durations across these phases is odd.

Failure for Correspondence across the Visual and Auditory Tasks

What is apparent from the results of this project is that there was not good correspondence among infants' performance across a visual and auditory task, as neither 4- or 8-months olds showed similarities in their attentional patterns. Importantly, there is a fundamental issue at hand that may elucidate this finding. With regard to the events used in this study, the visual events were static and the auditory events were dynamic. These findings may not necessarily be attributable to differences in attentional abilities or strategies of processing across modalities but may be a function of differences in infants' attentional processing of static verses dynamic events. There has been very little work investigating the developmental course of infant visual attention and recognition memory with dynamic visual events. This deficiency is not trivial and challenges the generality of what is known about infants' visual attentional abilities. At the very least, this finding highlights the need for further investigation of the impact of stimulus characteristics on infants' attentional responding and the corresponding mechanism that mediates the differences observed in performance. In order to address this issue, the use of dynamic visual events in a similar task should be used (instead of static one) that could better address information processing across modalities.

There is substantial support that infants pay more attention to dynamic events compared to static events. More recently within our own lab, it has been shown that older infants (6-months and older) show longer looking and longer periods of sustained attention to dynamic events compared to static ones. These results are suggestive that sustained attention could be a more sensitive parameter indicative of active processing of dynamic information, as it would not be advantageous to engage in prolonged looking to a static display. Additionally, this work is among the first to directly compare developmental changes across different types of events. The importance of the stimuli characteristics in the infancy literature has been largely underappreciated, particularly with regard to developing a more comprehensive understanding of changes in attentional abilities across the first postnatal year.

While none of the correlations across tasks were significant, it was interesting that the pattern of relationships changed with age. With recognized caution in these interpretations, it appears as though there were positive associations among the compared variables in the 4-month-old sample (with the exception of the peak look and peak listening trials in familiarization). In comparison, at 8-months of age, performance across tasks appeared to be negatively related. This could have developmental implications for the way in which infants become more efficient processors of dynamic and static information. It is reasonable to expect that young infants, who are not as facile with their attentional skills, attempt to process all information in much the same way. Therefore, the strategy for processing information would not change as a function of the event properties. Whereas older infants have acquired more experience and have learned how to be most efficient and flexible in their strategies for encoding information. In order to effectively process static visual events it would be prudent to be a short-looker, as the properties of the events are not changing. In contrast, the properties of a dynamic event change over time, so in order to fully process the information, it would be necessary to maintain attention over time (long-listening). Given the small sample size for these comparisons, it is difficult to determine if there are any such developmental trends, but the potential for further exploration in this area is exciting.

8-month-olds Lack of Visual Recognition Memory

While visual recognition memory was predicted, other work with infants at similar ages has also failed to show such recognition. For example, Rose et al. (2001) found that infants at 7 months were able to show recognition memory when the events used were of faces but no recognition was found when the events were of patterns. Additionally, Colombo et al. (2004) have shown that preferences for novelty decline over the first postnatal year and is absent after 9 months of age. Whatever factor(s) underlies this lack of recognition is unclear, as it would be expected that as infants get older, their ability to recognize events becomes better and more efficient. In this study, and consistent with the others is that the peak look duration and the mean looking time decreased compared to the 4-month-olds. There is a substantial body of data suggesting that look duration reflects, at least in part, the speed of obtaining data from the attended location, with shorter looking indexing faster processing.

One possibility for the lack of recognition in this study is that the events were not engaging enough to capture or maintain their attention. The properties of these events were very simplistic, therefore perhaps, using events which were more colorful or complex would have been more engaging for them. Although, given the lack of recognition in the Rose et al. (2001) when the events were more colorful, consisted of different shapes and patterns, it could be that these types of events are not interesting independent of the properties that compose them. As recognition was evident with the face stimuli, it is possible that the social nature of the events begins to play an important role with infants at this age.

Another possibility could be that the exposure time with these specific events (during the classification and familiarization phase) was too long for infants at 8 months of age. If this is the case, it is possible that the lack of recognition memory is not attributable to the fact that infants did not recognize the novel event, but that after such a long period of exposure, they had habituated to all events that were similar in nature (i.e. black and white geometric displays) and their attention was not likely to recover unless it

was to a more interesting event. One way to begin to investigate the interest in this task, would be to go back and calculate the overall amount of time that infants spent during the classification and familiarization phase (this would include the time attending to the events and the time spent in between events). If the ITIs are long, it may suggest that the level of interest in the task is quite low. Regardless, it is clear from the lack of recognition in this study, as well as others, there are many questions to be answered with regard to processes that underlie visual recognition memory and the characteristics of the events that are used with infants at this age.

Lack of Auditory Recognition Memory across Age

It was expected that there would be a similar pattern of attentional responding in an auditory recognition task, as there would be two groups of infants who differed in their recognition of auditory events. The results on this task are unfortunate as they fail to help elucidate how infants process auditory information. With regard to this study, it is unclear as to whether the lack of recognition is grounded in processing differences within the auditory modality or attributable to methodological design. The auditory task was designed to be as similar as possible to the visual task, in order to make cross-modality comparisons. It may be however, that there needs to be another design better able to detect recognition memory for auditory events. Even though there was nothing on the screen to visually process, the presentation of auditory information was contingent upon infants' looking toward the screen. Because it is possible that infants are paying attention auditorily without visual fixating at a central point, perhaps the presentation of auditory information should be contingent upon HR phase as compared to their looking behavior. This would involve the online monitoring of beat to beat changes in HR and would serve as an independent variable rather than a dependent variable. The cycling of HR (as proposed in Richards' model of attention) would hence drive the presentation of the auditory events. By doing so, it may help to identify group differences in processing that can not be obtained by using looking as the criteria for presentation of the event, as some infants may be actively processing and attending (auditorily) just not visual fixating toward the screen. Therefore, it maybe more beneficial to consider using the amount of time spent in sustained attention as a more informative variable for classifying the infant groups on an auditory task.

Another factor to be further explored is the amount of familiarization time needed to process auditory information. The familiarization time of event presentation during the classification and familiarization period was determined based upon the established time on a visual task. In order to keep task comparisons similar, and given the exploratory nature of the auditory recognition task, 20 s seemed reasonable. However, given the dynamic nature of the events themselves, it is possible that this was not enough exposure time to fully encode the events, which would have prevented recognition memory. As dynamic events are continually changing overtime, perhaps recognition could have manifested itself with longer periods of exposure, compared to the amount of time needed to process a static, unchanging display. Regardless, it is possible that the way in which infants were classified on the auditory task for this study was not the best way to establish group classifications that could identify differences in auditory processing abilities.

Future Directions and Conclusions

While this study failed to be prolific by way of generating statistically significance results in the comparison of infants' visual and auditory recognition

memory, it does generate many compelling questions worthy of further consideration. First, a systematic comparison of infant performance in a visual habituation task and their performance on the paired comparison task is necessary to better establish infants' visual recognition memory. As mentioned earlier, if these tasks are not equivalent in the amount of cognitive resources being demanded, generalizations as to infants' processing abilities becomes incomplete. Second, it will be important to further investigate how infants process dynamic versus static events and how this may change developmentally over the course of the first year. As a prime example, consider infants' social exchanges with caregivers and others. In order to effectively interact, as well as learn language, infants must learn how to pay attention to the facial and vocal cues being conveyed to them. These events are dynamic by nature and are deserving of further exploration as to the ways in which they impact infants' attentional responding. Finally, given the extensive literature on infants' visual attention and the individual differences observed with regard to processing static information, it may be worthwhile to seek to establish the sources of individual differences that occur within other modalities. Because attention is not limited to visual processing, starting from the beginning and establishing variables that distinguish information processing abilities within other modalities will only round-out our understanding of the organization of an infant's attentional system.

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Appendix A
**GREETINGS FROM THE
INFANT PERCEPTION LABORATORY!!!**



**DEPARTMENT OF PSYCHOLOGY
VIRGINIA TECH**

Soon after infants are born, they can recognize many different objects, sounds and voices. Even though babies are not yet talking, we believe that they are actively listening and paying attention to people and events in the world around them. We are interested in studying how auditory and visual events affect the attention of infants, because this helps us to understand how infants begin to learn, speak, and develop relationships with those around them.

There have been a lot of studies done exploring what types of visual objects infants pay attention to and find very interesting. We are interested in understanding more about sounds and voices that infants find exciting and how their attention develops and changes over the first year of life. If an infant is really interested in what they see and hear, they will look a long time and their heart rate will slow down.

If you have the time and interest, ***we would love to have you participate in one of our studies!*** Your participation would involve one visit to the Infant Perception Lab, located on the 3rd floor of Williams Hall on the campus of Virginia Tech (a map is enclosed for your convenience). **We are interested in infants at 4 months of age.** We will schedule a 30 minute appointment with you at your convenience (nights and weekends are available if you prefer). If there are older children in the family and you would like to bring them along, we offer free child care. We also have convenient parking next to our building on campus. If you are interested in scheduling an appointment, or like to find out more about our work, please feel free to call us at **231-3972** or visit our website at **http://www.psyc.vt.edu/infant_speech/pages/Homepage.htm**.

Sincerely,

Robin Panneton Cooper, Ph.D.
Associate Professor
cooperr@vt.edu

Megan McIlreavy, M.S.
Graduate Researcher
mmcilrea@vt.edu

Appendix B

VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY

Informed Consent for Participants in Research Projects Involving Human Subjects

Title: Individual Differences in 4-month-old Infants' Attention to Visual and Auditory Events

Principle Investigators:

Dr. Robin Panneton

Megan McIlreavy, M.S.

I. Purpose of this Research/Project

The purpose of this project is to investigate 4-month-old infants' attention to visual and auditory events and explore their pattern of heart rate activity as they are processing information. Your participation in this study benefits the study of early visual and auditory perception, particularly our understanding of the development of infant attention.

II. Procedures

Your infant will be tested for approximately 10 minutes, provided that he/she is quiet and awake. The baby will be held by the parent in her/his lap, facing a black panel. The baby will view a video screen on which either a black and white pattern or an illuminated screen will be presented. When the infant is presented with the black and white visual object, it will remain on the screen until your infant has looked at it for 20 seconds. Next, they will have the option of looking at the same object or a different object (they will have this option twice). When the illuminated screen is presented, your infant will get to listen to a melody until they have heard it for 20 seconds. Next, they will be presented with an illuminated screen and have the choice of listening to the same melody they just heard or a new melody (they will have this option twice). The infant can look and listen as long as he/she finds the display interesting. The loudness of the melody being played to the infant is no more than that heard by infants in their typical home environment. While the infant is looking and listening, we will be recording his/her heart rate as a measure of interest in the display. This heart rate measure involves placing three, pediatric electrodes on the infant's chest, using small adhesive strips that capture the recording. Also, each infant will be videotaped during his/her session for subsequent coding of their facial expressions. If for any reason, your infant cries or falls asleep, testing will be discontinued.

III. Risks

There are no apparent risks to your infant or to yourself for participation in this study. Sound levels for all auditory events and for the parent's headphones will all be verified prior to the testing of each subject. The pediatric electrodes are designed for sensitive skin, easily removable, and will be thrown away following testing.

IV. Benefits

There are no direct benefits to the participants in this study. Parents will receive a certificate of appreciation and the results of the study will contribute to a broader body of research on infant attention.

V. Extent of Anonymity and Confidentiality

All of the information gathered in this study will be kept confidential and the results will not be released without parental consent. However, the results of this project may be used for scientific and/or educational purposes, presented at scientific meetings, and/or published in a scientific journal. You will be sent a summary of the work when this project is completed.

VI. Compensation

There is no compensation to be earned from participation in this project.

VII. Freedom to Withdraw

You have the right to terminate your infant's involvement at any point in time and for any reason should you chose to do so.

VIII. Subject's Responsibilities

I voluntarily agree to have my infant participate in this study.

IX. Subject's Permission

I have been given an opportunity to ask further questions about this procedure and I understand that I have the right to end this session for any reason if I so choose. This project has been approved by the Human Subjects Committee of the Department of Psychology and the Institutional Review Board of Virginia Tech. If I have any questions regarding this research and its conduct, I should contact one of the persons named below. Given these procedures and conditions, I give my permission to Dr. Panneton and her co-workers to test my son/daughter.

Dr. Robin Panneton, Principle Investigator	231-5938
Megan McIlreavy, Graduate Research Assistant	231-3972
Dr. David Harrison, Chair, Human Subjects Committee	231-4422
David M. Moore, DVM, Assistant Vice Provost for Research Compliance	231-4991

Signature of Parent: _____

Date: _____

Infant's Name: _____

I would like to be contacted by phone regarding future studies: YES NO

MEGAN E. MCILREAVY

VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY
DEPARTMENT OF PSYCHOLOGY
WILLIAMS HALL
BLACKSBURG, VA 24061-0436
EMAIL: MMCILREA@VT.EDU

EDUCATION:

- 2003- present** Virginia Polytechnic Institute and State University- Blacksburg, Virginia
• Department of Psychology: Developmental and Biological Sciences
Doctor of Philosophy Degree- May 2006 graduation
Faculty Advisor: Robin Panneton, Ph.D.
Psychology Dissertation: Looking and Listening Patterns in 4-Month-Old Infants: Correspondence between Measures of Attention across Modalities
- 2000- 2003 Virginia Polytechnic Institute and State University- Blacksburg, Virginia
• Department of Psychology: Psychological Sciences Program
Master of Science Degree
Psychology Thesis: Behavioral and Psychophysiological Responses of 4-month-old Infants to Differing Rates of Infant Directed Speech
- 1996-2000 Virginia Polytechnic Institute and State University- Blacksburg, Virginia
• Department of Psychology:
Bachelor of Science Degree in Honors; Cum Laude
Honors Program: Honors Baccalaureate Degree
Psychology Thesis: The Inability of Infant-Directed Speaking Rate to Elicit Preferences in 8-Month-Old Infants
• Department of Communication Studies: Public Relations Emphasis
Bachelor of Arts Degree; Cum Laude

RECENT COURSES TAUGHT:

Psyc 2034 Developmental Psychology
Psyc 2004 Introduction to Psychology

MANUSCRIPTS/ BOOK CHAPTERS IN PREPARATION:

Panneton, R., **McIlreavy, M.**, Cooper, J., Ostroff, W., & Aslin, R.N. Developmental differences in infants' behavioral and psychophysiological attention to exaggerated duration in infant-directed speech. Manuscript under review at *Language Learning and Development*.

Panneton, R., **McIlreavy, M.**, & Bhullar, N. Preverbal communication. Book chapter in preparation for the *Encyclopedia of Infant and Early Childhood Development*.

ABSTRACTS PUBLISHED:

Panneton, R., & **McIlreavy, M.** (June, 2005). Developmental changes in 4- and 8-month-old infants' attention to infant-directed speech that differs in segmental duration. Abstract published in the proceedings from the International Speech Communication Association: Workshop on Plasticity in Speech Perception, London, England.

CONFERENCE PRESENTATIONS:

McIlreavy, M., Panneton, R., & Aslin, R.N. (June, 2006). Changing patterns of attention to static and dynamic visual events during infancy. Poster accepted for presentation at the International Conference on Infant Studies, Kyoto, Japan.

Panneton, R., & **McIlreavy, M.** (February, 2006). Interactions between visual and auditory events modulate infants' attention as a function of task and age. Presentation at the James S. McDonnell Workshop, Chicago.

Panneton, R., & **McIlreavy, M.** (June, 2005). Developmental changes in 4- and 8-month old infants' attention to infant-directed speech that differs in segmental duration. Poster presented at the ISCA Workshop on Plasticity in Speech Perception, London, UK.

McIlreavy, M., Bhullar, N., & Cooper, R.P. (May, 2004). Behavioral and psychophysiological indices of infants' attention to differing rates of infant-directed speech. Poster presented at the International Conference on Infant Studies, Chicago, IL.

McIlreavy, M., Hoffman, K., & Cooper, R. P. (April, 2003). Father recognition in 9-12-month-old infants. Poster presented at the Society for Research in Child Development, Tampa, Florida.

McIlreavy, M.E., & Cooper, J.S. (April, 2001). Infants' preference for slow rates of Infant- directed speech diminishes with age. Poster presented at the Society for Research in Child Development, Minneapolis, Minnesota.

PROFESSIONAL SERVICE:

Reviewer, Developmental Psychology (with Robin Panneton), 2006.

Reviewer, Abstracts Division 7, American Psychological Association, 2003.

PROFESSIONAL MEMBERSHIPS:

Society for Research in Child Development

International Society for Infant Studies

HONORS/AWARDS:

2005: Graduate Research and Dissertation Project Award
2004: Graduate Student Assembly Research Travel Award
2003: Graduate Student Assembly Research Travel Award
2001: Galper Fund, Virginia Tech Department of Psychology Travel Award
2001: Graduate Student Assembly Research Travel Award

SELECTED LEADERSHIP/SUPERVISORY ACTIVITIES:

2000 – present: Graduate Research Assistant to Dr. Robin Panneton
Instructor for undergraduate courses (see above)
Infant Perception Laboratory manager
Supervised undergraduate minority scholars in research advancement programs
Trained all of the personnel for the Infant Perception Laboratory
Supervised undergraduate honors students for their independent research projects
Teaching Assistant to Dr. Martha Ann Bell
Finalist for the Graduate Student Representative to the Board of Visitors