AGE AND INDIVIDUAL DIFFERENCES IN INFANT VISUAL ATTENTION AND ORAL EXPLORATION DURING AN OBJECT EXAMINATION TASK

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AGE AND INDIVIDUAL DIFFERENCES IN INFANT VISUAL ATTENTION AND ORAL EXPLORATION DURING AN OBJECT EXAMINATION TASK

by

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Abstract

The primary purpose of the present study was to investigate age and individual differences in visual attention and oral exploration in 6- and 11-month old infants. An infant-controlled habituation procedure with an object examination task was used to assess visual attention and oral exploration. This task yields the visual components of *casual looking* (a passive form of attention) and *examining* (an active form of visual information processing), and a measure of oral exploration, *active mouthing*. In addition, use of the object examination task allowed infants to be categorized as long or short lookers based on a median split of their peak *examining* times on the habituation trials. Performance on the object examination task was then compared to performance on the Fagan Test of Recognition Memory. Results revealed that long lookers scored lower than short lookers on the Fagan test, indicating that the individual differences in *examining* may influence performance on other visual attention tasks. In addition: (1) long lookers took longer to habituate than short lookers, (2) 6-month-olds engaged in more *casual looking* but less *examining* than 11-month-olds during habituation, (3) long lookers spent more time in *casual looking* and *examining* than did short lookers during habituation, (4) 6-month-olds engaged in significantly more *active mouthing* followed by *examining* than 11-month-olds. Therefore, younger infants do not appear to engage in as much active *visual* processing as older infants, but may use *oral* behaviour as a means of exploration. Furthermore, short lookers did not engage in as much *examining* as long lookers, which may be a reflection of their more efficient visual processing ability. These findings are important as they indicate

that measures of active information processing such as *examining* and *active mouthing* should be considered when assessing the developing cognitive capabilities of young infants.

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Age and Individual Differences in Infant Visual Attention and Oral Exploration During an Object Examination Task

Infants' visual attention during the habituation and paired-comparison procedures has provided a wealth of information about the development of their sensory and cognitive abilities. For example, data based on these procedures have shown that visual acuity, contrast sensitivity, and colour vision are poor at birth but rapidly develop over the first postnatal year (Courage & Adams, 1990; Dobson & Teller, 1978; Kellman & Arterberry, 1998; Adams, 1995). In addition, these methods revealed that newborns prefer faces to non-face stimuli of equal size and contrast and further, that they show a preference for their own mothers face over that of a stranger (Pascalis, de Schonen, Morton & Dervelle, 1995). Young infants also demonstrate the beginnings of category formation. For example, 3-month-olds are able to discriminate between pictures of animals and furniture (Behl-Chadha, 1996). In addition to discrimination, an important implication of these preferences is that infants possess rudimentary recognition memory from birth, or in the case of auditory recognition memory, perhaps even prenatally (DeCasper & Prescott, 1984; DeCasper & Spence, 1986; for reviews, see Cohen & Gelber, 1975; Fagan, 1990; Slater, 1995).

Fantz (1964) was the first to use the habituation and paired-comparison procedures to study infant perception and found that infants preferred certain stimuli over others and could therefore discriminate among stimuli (Fantz & Nevis, 1967). These findings also indicated that from birth infants could encode, store and retrieve information.

More recently, these procedures have become interesting in their own right as there is evidence that they may provide information about the functioning and development of human information processing. In particular, researchers have attempted to use individual differences in infants' visual attention on habituation and paired-comparison tests to predict cognitive ability in childhood (Colombo & Mitchell, 1990, Rose & Feldman, 1990; Ruff, 1990). Individual differences in several measures of infant performance on habituation and paired comparison tasks predict performance on concurrent tests of cognitive performance in infancy and on later measures of language, cognition, and representational play during childhood (Bornstein, 1998; Colombo, 1993; McCall & Carriger, 1993; Rose & Feldman, 1990). Furthermore, because these individual differences are evident in early infancy, it would be useful to establish their origins. Although the exact origins are not known, various hypotheses have been proposed, including possible differences in visual system mechanisms and processes (e.g. Frick Colombo & Saxon, 1999; Colombo, 1995), or differences in temperament, and/or mother-child interactions (Miceli, Whitman, Borkowski, Braungart-Rieker, & Mitchell, 1998; Miller, Miceli, Whitman, & Borkowski, 1996).

In the following sections, a brief review of the literature on habituation and paired-comparison procedures will be provided. Next, subsequent research on individual differences, and their predictive value, will be described. Finally, an experiment will be proposed in which individual differences in the development of infants' visual attention and oral exploration on a habituation task will be examined in relation to their performance on tests of recognition memory, their heart rate, and temperament.

Traditional methods for assessing infant visual attention

Visual Habituation

Habituation is defined as a decrement in response following repeated presentation of a particular stimulus. It is considered by many to be a basic form of learning seen in human and nonhuman species. The most usual explanation of the process of habituation is based on Sokolov's comparator model (Sokolov, 1963). In this model, habituation occurs as the repeatedly presented stimulus forms an engram or trace in the organism's brain. As the engram and the external stimulus become more similar, attention wanes because the stimulus has been fully encoded. One problem with this model is that it cannot explain why infants disengage fixation to the stimulus prior to being habituated. More specifically, some infants disengage fixation, which indicates that they are habituated to the stimulus, but then immediately reestablish fixation to the stimulus (Colombo & Mitchell, 1990). Modifications to the theory since Sokolov's initial proposal have attempted to address this (Colombo & Mitchell, 1990). For example, it may be that infants are not habituating to the object as a whole, but to small pieces of it, thus when the infant looks away, habituation *to a particular area* of the stimulus has occurred (Olson, 1976). A number of additional alternatives to the Sokolov model have been proposed to explain the habituation process, all of which imply that some sort of learning is occurring over time (for a review, see Colombo & Mitchell, 1990).

Habituation procedures have been modified over the years. Initially a fixed-trial procedure was used in which the number and duration of presentations of the stimulus was determined by the experimenter. That is, all infants were exposed to the stimulus for the same amount of time or number of trials. The problem with this was that it failed to take individual differences into account. For example, because infants were habituating at different rates, some would require only brief exposure to habituate while others would require more prolonged exposure (Colombo & Mitchell, 1990). As a result infants who required prolonged exposure would not fully habituate, presumably because they had not entirely encoded the stimulus. Other individual difference measures derived from habituation such as the time to habituate, the number and duration of looks infants made, and the duration of the peak look, were also masked in the fixed trial procedure. To resolve these problems, the *infant-controlled* procedure was developed (Horowitz, Paden, Bhana & Self, 1972). In this procedure infants are exposed to the stimulus until they reach a pre-determined decrement in looking time. The 'criterion' is then defined as the point where habituation is complete, or the end of the decrement in looking time. This criterion is determined by the experimenter, with infants varying on the time and number of looks taken to reach it. In addition, the stimulus is not presented until the infant's attention is focussed on the location where it will appear. Therefore, the infant's attention is elicited by the experimenter before the stimulus is presented (Bornstein & Benasich, 1986). Later refinements include the "floating criterion", defined as two consecutive trials with times 50% or less than the previous longest trial. The term 'floating' is used because the criterion can change depending on the length of the trials during habituation (Moss, Colombo, Mitchell & Horowitz, 1988). It also adjusts for the fact that infants do not always show a linear decrement in looking time with increased exposure. Some infants may have a peak looking time towards the end of or in the middle of the habituation phase (Bornstein & Benasich, 1986). For example, if the infant's initial trial time was 20 sec, the criterion would be two consecutive trials at 10 sec or less. However, if in a later trial the time was 30 sec, the criterion would then be changed to two consecutive trials at 15 sec or less. This procedure also enables the researcher to identify individual differences in total looking time, such as the speed of habituation, peak look duration, and the number and duration of fixations before habituation (e.g. Colombo, Richman, Shaddy & Maikranz, 2001; Colombo, Mitchell, O'Brien, & Horowitz, 1987).

One early criticism of the habituation procedure as a measure of learning included the claim that decrements in response were not due to encoding of the stimuli or learning, but rather were due to fatigue. This is unlikely, however, as the infant's attention can be easily reestablished subsequently with the presentation of a novel stimulus (where the infant increases looking) but is not reestablished during test trials when the habituated stimulus is presented (where the infant fails to increase looking) (Colombo, 1993, p.34).

Another criticism of the habituation procedure is its low short- and long-term reliability from one testing session to the next (McCall & Carriger, 1993). However, this test-retest reliability is dependent upon the habituation measure that is used and the time between test sessions. For example, when *total trial times* are used as the measure, test-retest reliability can be low because these times can vary in duration from one test session to the next. In this case, trial time may not necessarily reflect the amount of time that the infant actually *looks* at the stimuli. However, when *look duration* is used as the primary measure, test-retest scores show modest reliability for this measure and stability within individuals is reasonable (Colombo & Mitchell, 1990). Infants, therefore, tend to exhibit similar look durations from one test time to the next. In addition, Colombo and colleagues (Colombo, 1993, p. 47; Colombo, Mitchell, Coldren & Freeseman, 1991; Colombo & Mitchell, 1990) have argued that the stability of other measures such as the number of fixations also seem to rely on duration of fixation. Furthermore, patterns of habituation, for example, whether an infant exhibits a sustained decrement in looking time with repeated exposure, have demonstrated modest *short-term* test-retest reliability. For example, Bornstein and Benasich (1986) reported moderate stability as 66% of infants retained the same pattern of habituation when re-tested 10 days later. Despite this, reliability, particularly long-term reliability must be taken into consideration by researchers who are using measures of visual attention in infancy to predict cognitive performance in later childhood (Rose & Feldman, 1997; Rose, Feldman & Wallace, 1988; Rose & Wallace, 1985).

Paired Comparison

The second major type of procedure that has been used to examine infant perception and cognition is the *paired-comparison task* (Fantz, 1964). This procedure differs from habituation because the infant is not necessarily exposed to a stimulus long enough to become habituated. Instead, the infant is shown a pair of identical stimuli for a predetermined typically brief familiarization interval, during which time the infant may or may not habituate. Looking time to each stimulus is then recorded. After familiarization, the familiar stimulus is paired with a new (novel) stimulus on a test trial, and looking times to each are measured. If the infant discriminates and, therefore, recognizes the familiar stimulus, he or she should then show a preference for the novel stimulus. Operationally, a 'novelty preference' results if the infant fixates the novel stimulus for significantly more than 50% of the total trial time. As with the habituation procedure, researchers using the paired-comparison procedure also measure look duration, peak look duration, and number of looks. In addition, the number of shifts between stimuli is recorded.

The paired-comparison method is also considered to be a measure of information processing ability because it measures how well infants can encode, store, and retrieve information about a stimulus. Encoding ability is measured by the amount of familiarization time the infant requires to fully process the stimulus. Researchers have found that younger infants require more familiarization time than older infants, but the exact amount of time required varies with age and stimulus complexity (Fagan, 1991). Storage is then tested by manipulating the time between familiarization and novelty trials, to see whether the representation of the stimulus stays in memory. Finally, retrieval is tested during novelty trials, where the infant must recognize the *familiar* stimulus and, therefore, fixate on the *novel* stimulus for a longer period of time. Furthermore, there is evidence that performance on paired-comparison tasks can be predictive of aspects of later intellectual ability as it relies on some of the same abilities that are assessed in standard IQ tests for adults, namely recognition memory, discrimination and speed (Colombo and Mitchell, 1990).

Individual Differences and Infant Visual Attention

There is evidence that there are individual differences in infant information processing (e.g. Jankowski, Rose, & Feldman, 2001; Jankowski & Rose, 1997; Colombo, 1993; Freeseman, Colombo, & Coldren, 1993; Colombo, Freeseman, Coldren, & Frick, 1995; Bronson, 1991; Colombo, Mitchell, Coldren, & Freeseman, 1991). The primary reason for investigating these differences is to uncover the components of visual attention and variations that exist among infants on tasks of visual attention. There are many theories which attempt to account for these components of visual attention. One theory, proposed by Bornstein and Benasich (1986), aims to explain individual differences in terms of the pattern of *habituation*. A second theory comes from Colombo (2000; 1993; Colombo & Mitchell, 1990) and stresses the importance of using *look duration* as the primary measure of individual differences in these tasks. Look duration has also been used to describe individual differences in visual attention. More specifically, infants have been classified as "short" or "long" lookers based on the duration of their longest or *peak* look at a stimulus during familiarization or habituation trials (Jankowski, Rose, & Feldman, 2001; Jankowski & Rose, 1997; Colombo, 1993; Freeseman, Colombo, & Coldren, 1993; Colombo, Freeseman, Coldren, & Frick, 1995; Bronson, 1991; Colombo, Mitchell, Coldren, & Freeseman, 1991). One view is that these classifications are thought to reflect differences in encoding speed (Jankowski & Rose, 1997; Colombo, 1993; Colombo, Mitchell, Coldren, & Freeseman, 1991).

A second reason for investigating individual differences in infant information processing is that recent evidence suggests that certain measures derived from the habituation and paired-comparison procedures may be useful as early screening tools. These are used to detect problems in cognitive development associated with, for example, premature birth (Rose, Feldman & Jankowski, 2001).

Variations in Habituation Style

In a study of individual differences and short term reliability of habituation patterns in 5-month-olds, Bornstein and Benasich (1986) have shown that there are three different styles of habituation: (1) exponential decrease, (2) increase-decrease and (3) fluctuating. These styles are defined by the location of the infant's peak trial time. In the exponential decrease pattern, trial durations decrease as a function of exposure time with the longest trial occurring at the beginning of the test. All subsequent trials are shorter in duration than the first. Bornstein and Benasich (1986) found that the majority (60%) of infants exhibited this type of habituation. In the second style, increase-decrease, the function is unimodal, where trial times are greater for at least two consecutive trials following the first trial and decrease thereafter. Only 10% of infants fit this pattern of habituation. Finally, if the habituation function is at least bimodal, then a fluctuating pattern has occurred. In this case, there are at least two increase-decrease patterns, with attention continuing to increase, then decrease across trials. This was the second most common pattern with 30% of infants exhibiting this form of habituation. These three different functions indicate that habituation does not always involve a linear decline in trial time as a function of exposure time. Rather, infants vary in their pattern of habituation, and may have one peak trial or several peak trials at various points during the habituation process. Furthermore, infants who show these different patterns also vary in the length of time they fixate the stimuli, and in the number of looks that they take to reach criterion. More specifically, infants who show an exponential decrease take the least amount of time to reach criterion, have the fewest number of looks and the steepest decrement in overall looking time. Because of this it has typically been assumed that the most mature and efficient form of habituation is that of the exponential decrease. Furthermore, Bornstein and Benasich claim that the number of infants who demonstrate a particular function is not affected by the type of stimulus used (Bornstein & Benasich, 1986).

Variations in Look Duration

Bornstein and Benasich's (1986) primary focus is the location of *peak* look duration during habituation. Fundamentally however, *overall* look duration is the most basic measure of attention as it represents the total amount of time the infant spends looking at a particular stimulus (Brennan, Ames & Moore, 1966; Cohen, 1972; Fagan, 1970). Other measures such as the peak look duration, the number of shifts from one object to another, and the number of looks, are dependent upon look duration. As Colombo states: "parameters of visual attention and habituation may all be reducible to differences in the duration of fixation" (Colombo, Mitchell, Coldren, & Freeseman, 1991, p. 1247). Both overall look duration and peak look duration are crucial measures for the visual habituation task (Colombo, Mitchell, Coldren & Freeseman, 1991; Colombo, Mitchell, O'Brien & Horowitz, 1987; Bornstein & Benasich, 1986; Cohen, 1972; Fagan, 1970; Brennan, Ames & Moore, 1966). Furthermore, look duration is crucial to the paired-comparison procedure as it indicates which stimulus an infant prefers.

In reviewing the concept of look duration, Colombo (Colombo & Mitchell, 1990; Colombo et al., 1991) has drawn four basic conclusions. The first is that look duration shows the most predictable change as a function of age as younger infants show longer look durations than older infants. Second, duration of fixation or look duration shows the highest test-retest reliability and within subject stability. Third, other measures of attention seem to be dependent on look duration, such as the number of trials to habituation. Finally, look duration has been shown to correlate negatively with cognitive performance (e.g. verbal ability) later in childhood. More specifically, as look duration increases, cognitive performance tends to decrease (Colombo, Mitchell & Horowitz, 1988).

"Short-" versus "Long-lookers"

Researchers have demonstrated that there are fundamental differences in the way infants process visual stimuli. For example, Bornstein and Benasich (1986) propose that differences lie in the habituation pattern. Colombo however, claims that fundamental differences exist in look duration (1991). As a consequence of this, Colombo and colleagues have identified infants as "long" or "short" lookers based on their *peak look duration* during habituation or familiarization (Jankowski, Rose, & Feldman, 2001; Jankowski & Rose, 1997; Colombo, 1993; Colombo, Freeseman, Coldren, & Frick, 1995;

Bronson, 1991; Colombo, Mitchell, Coldren, & Freeseman, 1991). Namely, short lookers are thought to demonstrate fast encoding times and quick and frequent fixations and shifts relative to their long looking counterparts. This difference is demonstrated in paired-comparison tasks by manipulating familiarization time. Because of their faster encoding ability, short lookers do not appear to require as much familiarization time as long lookers. As a result, after very brief familiarization periods, short lookers tend to show a novelty preference, indicating that they have encoded the stimulus. On the contrary, long lookers tend to show a familiarity preference, an indication of incomplete encoding.

Information Processing Tasks and Later Cognitive Ability

One of the primary reasons for investigating individual differences in information processing is to determine whether there is a link between performance on those tasks and later cognitive ability. Traditional assessments such as the Bayley Scales of Infant Development (Bayley, 1969) have failed to do this. For instance, although the Bayley Scales can be used to detect obvious developmental deficits, it is not capable of predicting later cognitive ability with any accuracy as it relies primarily on sensorimotor skills (McCall & Carriger, 1993). Currently, researchers use the habituation and paired-comparison procedures to assess early information processing skills such as encoding, storage and retrieval that are believed to be related to later cognitive ability (Colombo, 1993). Results from these studies do seem to indicate a link between visual processing in infancy and later IQ tests. More specifically, fixation duration in infancy has shown moderate stability within individuals and is correlated with concurrent measures of cognitive performance (e.g. recognition memory) and with performance on tests of intelligence, cognition, and language at various points in later childhood (Colombo, 1993). For example, studies have indicated a positive relationship between cognitive performance in infancy and childhood IQ (e.g. Colombo & Mitchell, 1990; Rose & Feldman, 1990; Ruff, 1990; Rose, Feldman & Wallace, 1988; Rose & Wallace, 1985), and measures of recognition memory and novelty preferences have been found to predict cognitive (e.g. language) ability in preschool and school-age children (Rose & Feldman, 1997; Rose, Feldman, Wallace, & McCarton, 1989; Thompson, Fagan, & Fulker, 1991). In addition, two meta-analytic studies have been reported (McCall & Carriger, 1993; Bornstein & Sigman, 1986). Specifically, McCall and Carriger (1993) found an overall correlation of .36 between habituation and recognition memory assessments in the first year of life and IQ at various points from ages 1-8 years. This appears to be a robust finding as it is not limited to one lab, one particular criterion of attention, or to special populations such as infants with Down's Syndrome or developmental anomalies. Bornstein and Sigman (1986) also reviewed the research examining the continuity of cognitive development from infancy to later childhood and also conclude that a relationship may exist between performance on tasks of information processing in infancy and later cognitive ability.

Habituation is a basic form of learning, and, therefore, it may have predictive ties to later cognitive and intellectual ability (Colombo, Mitchell, O'Brien, & Horowitz, 1987). There is evidence to support this. Studies have reported modest correlations between assessments of habituation and recognition memory and childhood intelligence (Fagan &

McGrath, 1981; McCall & Carriger, 1993; Rose & Feldman, 1987; Rose, Feldman, Wallace & McCarton, 1991; Rose, Slater, & Perry, 1986). This suggests that perhaps we can predict intelligence in later childhood using visual attention tasks in infancy.

Casual Looking versus Examining and Infant Visual Attention

Visual attention can be broken down into different components, depending upon the task that is used to assess it. Bornstein and Benasich (1986) and Colombo (e.g. Colombo, Freeseman, Coldren & Frick, 1995) have used habituation and paired-comparison tasks with static, 2-dimensional stimuli. These methods have yielded a wealth of information regarding individual differences in infant visual attention. Other researchers have employed a habituation procedure using an object examination task (e.g. Oakes & Tellinghuisen, 1994; (Ruff, Saltarelli, Capozzoli, & Dubiner, 1992; Oakes, Madole, & Cohen, 1991; Ruff, 1986). In contrast to the static, 2-dimensional stimuli of previous research, this task uses 3-dimensional objects that the infant can manipulate. In addition, this task is most effective in differentiating between what Ruff (1986) refers to as *examining* versus *casual attention (casual looking)*. Casual looking is a passive glancing behaviour often accompanied by the infant banging the toy, placing it in the mouth and so forth (Ruff & Lawson, 1990; Ruff, 1986). In contrast, examining is characterized by an "intent look on the face", pointing to specific parts of the object, and prolonged fixation (Ruff, 1986). It is typically seen when a novel object is first presented and varies in length depending on the complexity of the object and the age of the infant (Oakes & Tellinghuisen, 1994; Richards & Casey, 1992). Unlike casual looking, examining tends to decline and eventually disappear with increased exposure time to an object (Ruff, Saltarelli, Capozzoli, & Dubiner, 1992; Oakes, Madole, & Cohen, 1991). Furthermore, infants are less distractible during examining than during casual looking (Doolittle & Ruff, 1998; Ruff, Capozzoli, & Saltarelli, 1996; Oakes & Tellinghuisen, 1994). Although examining time has been shown to increase with *object complexity* (Oakes & Tellinghuisen, 1994), and *age* (Colombo, Richman, Shaddy, & Maikranz, 2001; Oakes & Tellinghuisen, 1994) the relationship among these variables is a complex one that requires further research. Furthermore, very little is known regarding individual differences in casual looking and examining.

Another term for "examining" is "*sustained attention*" (Richards, 1985). Sustained attention is the common term used in studies in which physiological measures such as heart rate are used to measure attention. Just as Ruff differentiates between casual looking and examining, Richards and colleagues (Richards & Cronise, 2000; Richards & Gibson, 1997; Richards, 1985) argue that attention is made up of *three* components: (1) orienting, (2) sustained attention, (3) attention termination (Richards, 1985). Orienting occurs when the infant first fixates the stimulus. Once the stimulus has been fixated, the infant may then exhibit sustained attention, which is comparable to examining in that it involves active information processing. Furthermore, like examining, infants engaged in sustained attention are more difficult to distract than those not engaged in sustained attention (Richards, 1989b). Attention termination then occurs when the infant disengages from the stimulus. There is evidence that changes in heart rate correspond to these three components (for a review, see Richards & Casey, 1992): (1) an initial decrease from baseline, (2) the decrease from baseline is maintained, and (3) a return to baseline respectively. When the infant first orients to a stimulus, there is a deceleration in heart rate. If the infant then engages in sustained attention, the significant decrease in heart rate is maintained. Finally, when attention termination occurs, heart rate returns to its original level prior to orienting. The components of orienting, sustained attention and attention termination have also been replicated by Colombo and colleagues (Colombo, Richman, Shaddy & Maikranz, 2001) using the habituation procedure.

Variations in Oral Exploration

Researchers who have used the object examination task to investigate differences in *visual* behaviours such as casual looking and examining have also assessed forms of *oral* exploration, such as mouthing. This behaviour peaks in infants around 7-months of age, who frequently mouth as well as fixate a new toy. This mouthing, when manifested as oral exploration, is also a form of examining. Furthermore, as with visual attention, there are also different components of mouthing: (1) active mouthing, and (2) other mouthing. Active mouthing is akin to visual exploration (e.g. examining) and is believed to be used to gather information (Ruff, Saltarelli, Capozzoli & Dubiner, 1992). This is contrary to other mouthing which is made up of behaviours such as sucking, which do not reflect actual information gathering (Ruff, Saltarelli, Capozzoli & Dubiner, 1992). Furthermore, *active mouthing* follows the same trajectory as examining as it decreases with repeated exposure (looking time) to an object. This indicates that the function of these behaviours is indeed exploratory. In addition, Ruff and colleagues (Ruff, Saltarelli, Capozzoli, & Dubiner, 1992) have found that periods of oral exploration (active mouthing) can be followed by visual exploration (examining). In this case, the infant appears to be switching back and forth between modalities, in an attempt to gain as much information about the object as possible. The development of haptic perception may also help to explain this finding (Bushnell & Boudreau, 1998; 1993). Haptic perception is the ability to gain information about an object using the hands. At 3- to 6-months of age infants are not able to use their hands to effectively explore object properties and so must use oral means. By 12-months of age however most infants are able to efficiently use their hands to explore objects (Bushnell & Boudreau, 1998; 1993). One important distinction between individual differences in vision and mouthing however, is that no attempts have been made to tie oral behaviours to performance on later cognitive tasks.

Individual Differences in Temperament

More recently, researchers have also claimed that individual differences on information processing tasks can partially be accounted for by temperament. Temperament is defined as "the *way* in which an individual behaves" (Thomas & Chess, 1977, p.9). It refers not to the fact that an individual *engages* in a particular behaviour, but rather *how* he or she engages in a particular behaviour (Thomas & Chess, 1977). For example, it can refer to how determined an individual is to finish a task (persistance), or how easily he or she can be distracted from a task (distractibility; Thomas & Chess, 1977). These and all other dimensions of temperament can determine how a person behaves in certain contexts

(Bates, 1994). It is, therefore, logical to assume that there are dimensions of temperament which can influence performance on information processing tasks. The most convincing link between temperament and measures of information processing comes from Miceli and colleagues (Miceli, Whitman, Borkowski, Braungart-Rieker, & Mitchell, 1998; Miller, Miceli, Whitman, & Borkowski, 1996). These researchers used measures of both fixation duration and novelty preference in an attempt to test the relationship between temperament and individual differences in visual processing. Four-month-old infants were given a paired comparison task, with their novelty preference scores and peak fixation duration recorded. In addition, parents filled out the Infant Behaviour Record section of the Bayley Scales (1969) as a measure of temperament, entailing components such as mood and adaptability, similar to those proposed by Chess and Thomas (for a review, see Chess & Thomas, 1996; Thomas & Chess, 1977). Maternal behaviour was also assessed by videotaping play sessions between mother and child. Mothers were rated on the amount of encouragement, sensitivity, emotion, and attentiveness displayed. Results revealed that although maternal behaviour did contribute to performance on the paired comparison task, those infants rated as responsive and positive in the questionnaire had shorter fixation times, indicating that they were processing the stimuli quicker than infants rated as having less energy and interest. Wachs, Morrow, & Slabach, (1990) found a similar relationship between performance on a recognition task and temperament, as measured by the Revised Infant Temperament Questionnaire (RITQ; Carey & McDevitt, 1978). These studies provide some evidence for a possible connection between information processing ability and temperament.

The Proposed Research

The present study has three main goals. The first is to investigate age and individual differences in 6- and 11-month olds' visual attention during an *infant-controlled* object examination task. Although Colombo and colleagues (Jankowski, Rose, & Feldman, 2001; Jankowski & Rose, 1997; Freeseman, Colombo, & Coldren, 1993; Colombo, Freeseman, Coldren, & Frick, 1995; Colombo, Mitchell, Coldren, & Freeseman, 1991) have found individual differences (e.g. short versus long lookers) using static, 2-dimensional patterns, it is not known whether these same differences would also be found using a different task. In accordance with this, the present study will use the object examination task and 3-dimensional infant toys to test individual differences between 6- and 11-month olds. In addition, instead of classifying "long" and "short" looking infants based on peak *look duration* (the longest look), the present study will use peak *examining* time (the longest period of examining). Duration of examining has been found to be the more sensitive measure of visual attention, as it is believed to be indicative of ongoing information processing (Oakes & Tellinghuisen, 1994; Ruff, 1986). It would, therefore, be of value to see whether differences exist between long and short lookers when they are classified in this manner. With regard to *examining* and *casual looking*, it is predicted that older infants (11-month-olds) will show a greater proportion of examining during looking than younger (6-month-old) infants (Colombo et al., 2001). It is also predicted that younger infants will engage in casual attention to a greater degree than older infants.

Furthermore, it is predicted that younger infants will require a greater amount of time and a greater number of trials to habituate to the toys than the older infants. Similarly, because they are believed to be faster processors, short lookers will habituate more rapidly than long lookers and will also require fewer trials to habituate.

The second goal of the present study is to establish whether performance on the habituation task generalizes to another cognitive task. More specifically, individual differences (short and long looking) found during habituation will be used to predict performance on another measure of information processing: the Fagan Test of Recognition Memory (see Fagan, 1990). The Fagan Test (see Fagan, 1990) is a paired comparison procedure. More specifically, the infant is given a brief familiarization interval in which to fixate a facial stimulus. Following this the infant is shown the previous (familiar) stimulus paired with a novel one. The score on the test then depends upon the amount of time that the infant spends looking at the novel stimulus. Furthermore, all infants of the same age are given the same amount of familiarization time, this means that they have a limited amount of time in which to fully encode the familiar stimulus. Therefore, it is predicted that only those who are fast, efficient processors (short lookers) will direct attention to the novel face, because these infants have fully encoded the familiar face. Most importantly, it is predicted that short lookers will also have higher novelty preference scores than long lookers.

A third goal of the study is to assess non-visual aspects of infants' attention to novel objects. The object examination task is well suited to this end as it can be used to test both visual and oral behaviours. Research shows that young infants combine both oral (mouthing) and visual information seeking as they explore new objects. This behaviour peaks at about 7-months of age and declines during the remainder of the first year. To assess this behaviour, *active mouthing* and *active mouthing* followed by *casual attention* and *examining* will be recorded during the object examination task. It is predicted that the 6-month-olds will engage in more *active mouthing* behaviour than the 11-month-olds.

In sum, the results of this study should add to current knowledge regarding age and individual differences in infant's visual attention. More specifically, this study is important for two theoretical reasons. First, infants are classified as short and long lookers using a measure that is believed to reflect actual information processing, thereby tapping into actual cognitive ability. Although it is already known that infants classified as long lookers differ from those classified as short lookers based on peak look duration, it is not known whether these differences exist when infants are classified based on peak examining time. The reason why previous researchers could not make this distinction is because examining time could not be measured for their tasks. Examining duration can only be derived from certain tasks, namely those employing object examination. Nevertheless, this is an important distinction to make, as *examining* is currently thought to reflect active information processing. Second, visual **and** oral means of exploration are considered because of younger infants' reliance on both these abilities. In addition, the present study assesses non-visual forms of information processing, namely, *active mouthing*. This is also an important distinction to make as younger infants use visual **and** oral methods to explore their environment. Furthermore, this study has important clinical implications. First, if it is found that long lookers (as classified by peak examining duration) score lower on the Fagan Test than short lookers, then it is possible that *examining* duration rather than *look* duration could be used as a basis for assessing cognitive ability in young infants. For example, screening tools which assess infant attention could be modified to use an object examination task, so that *examining* time could be measured. Second, if significant differences are found with regard to oral exploration, then it would suggest the need for clinicians to assess these abilities in younger infants when screening for possible cognitive/developmental problems.

Method

The general goal of the present study was to use two tasks to assess age and individual differences in infants' visual attention. The first was an object examination task using an *infant- controlled* habituation procedure. This task provided measures of both visual and oral exploratory behaviours. The infants' heart rate was recorded during this task in an attempt to obtain a physiological measure of attention similar to Richards (e.g. Richards & Cronise, 2000; Richards & Gibson, 1997; Richards, 1985). Another measure of attention was the *Fagan Infantest* (See Fagan, 1990) which assessed recognition memory using a paired-comparison procedure. In addition, infants' temperament was measured by parental report using the Revised Infant Temperament Questionnaire (RITQ; Carey & McDevitt, 1978).

Participants:

Twenty-eight 11-month-old and 26 6-month-old full-term infants were recruited for this study. Four of the 11-month-olds and three of the 6-month-olds were excluded from subsequent analyses because of fussiness/inattention (2), or incomplete data (5). The final sample consisted of 23 6-month-olds (M = 28.87 wks, SD = 1.74 wks) and 24 11-month-olds (M = 49.08 wks, SD = 2.99 wks). There were 12 male and 11 female infants in the 6-month-old group and 9 male and 15 female infants in 11-month-old group. Participants' names were obtained from their parents following a personal in-hospital contact at the time of the baby's birth. Parents who had expressed an interest in participating in research at the time of the baby's birth were contacted by phone and an appointment was arranged if they still wished to participate. All parents were white and predominately of middle socio-economic status.

Stimuli and Apparatus:

Two commercially available, plastic rattles were used as stimuli for the object examination task. The rattles were multicolored, approximately 15 cm x 10 cm in size, and contained several moving components. They differed in overall shape and configuration – one resembled a human form and the other an animal form. One of the rattles was used in the habituation phase of the procedure and the second one in the dishabituation or recovery phase. Toys were chosen to be age-appropriate for both younger and older infants.

A plastic booster seat equipped with a nylon safety belt and a plastic table was used to keep infants stationary during the object examination task. Infants were videotaped during this procedure using a *JVC* camcorder and habituation and test trials were timed with a digital stopwatch.

Heart rate was measured with a *Polar Performance* Heart Rate Monitor (Polar Electro Inc.). This device consisted of a rectangular transmitter approximately 4cm wide by 14 cm long. Connected to each end of the transmitter were wires 30 cm in length. Disposable electrodes were attached to the ends of both wires and these were attached to the infant's skin about 11 cm below each armpit. An LCD wrist watch containing a receiver was placed behind the infant and recorded his or her heart rate via a radio link with the transmitter.

Temperament was measured using the Revised Infant Temperament Questionnaire (RITQ; Carey & McDevitt, 1978), standardized for use with infants between 4 and 11 months of age. This scale consisted of 105 statements in the 9 categories identified by Thomas, Chess and colleagues (1963) which assesses the child's activity, rhythmicity, approach, adaptability, intensity, mood, persistence, distractibility, and threshold. The activity scale rated participants on how active they were, for example whether they sat still for long periods or tried to stay in motion. Rhythmicity related to whether the infants followed daily routines, such as sleeping and eating at regular times. The approach scale was based on how they responded to strangers, for example whether they became upset if a stranger attempted to pick them up. Adaptability was similar to this and measured how well infants adjusted to new situations. Intensity and mood related to overall disposition, such as whether they cried frequently or were irritable. Persistence by definition rated infants on how determined they were in everyday situations, whether they gave up easily when attempting to obtain an object, for example. Distractibility assessed how focussed infants were, whether they were able to fixate and concentrate on a task or were easily distracted. Finally, threshold assessed arousability, for example whether they were easily engaged by stimuli in their surroundings. Infants were rated on each statement using a 6-point Likert scale going from "almost always" to "almost never" based on how the statement fit the child's behaviour. The ratings for all 105 statements were then grouped to provide separate scores for each of the nine scales with high scores indicating a more positive temperament. All scores were calculated as standard deviations from standardized mean scores of 0 which represented the behaviour of "average" or "typical" children. These deviations ranged from -4 to +4, where a negative standard deviation represented a more difficult child while a positive deviation represented a more easy going child. While standardizing the revised version of the Infant Temperament Questionnaire, Carey and McDevitt reported test-retest reliability to be .86. The internal consistency of the RITQ was reported as .83 (Carey & McDevitt, 1978).

The *Fagan Infantest* (See Fagan, 1990) is a standardized test of visual information processing and recognition memory for infants between 6- and 12- months of age that employs a paired-comparison procedure. The test consists of 18 photos of human faces varying in age, gender and facial expression. Eleven photos were of female faces (9 monochrome, 2 colour), 2 photos were of male faces (1 monochrome, 1 colour), and 5 photos were of infant faces. All photos were printed on 18 cm x 18 cm squares of stiff paper with velcro attached to the back and were labelled with a letter. A wooden stage similar to that used for a puppet show was used to display the stimulus photos (see Figures 1A and 1B). The frame of the stage was approximately 50 cm high and 60 cm wide. Inside the frame was a wooden display panel on an axis that allowed it to swing 180°. One side of the panel faced the experimenter, while the other side faced the participant. The side facing the participant had two 3 cm^2 pieces of velcro, each halfway up from the bottom, and 1/3 of the way in from the side. Photos were attached to these velcro squares during testing. The center of the display panel contained a peephole approximately 5mm in diameter that was used to observe the infant's eye movements.

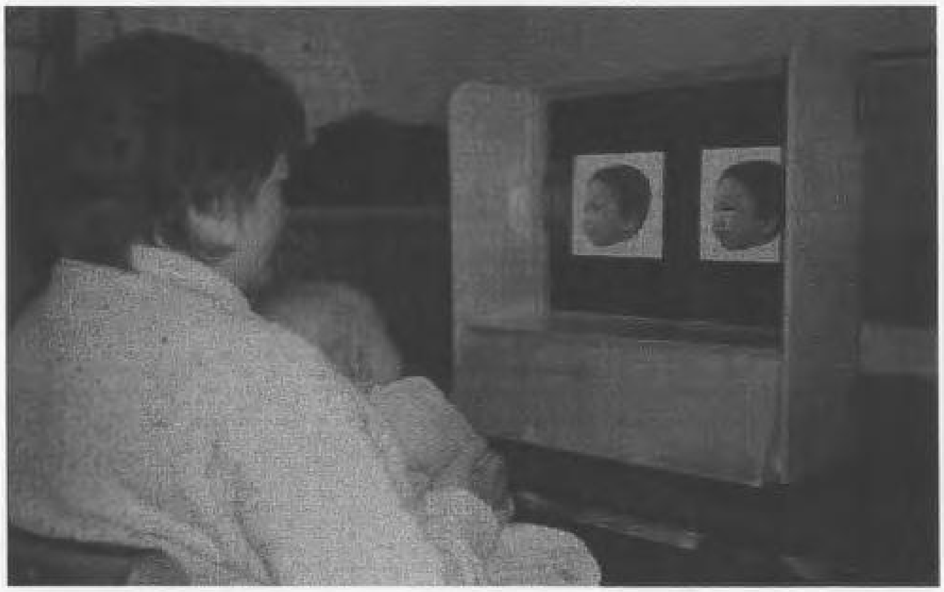

Figure 1A. A demonstration of the Fagan Test of Recognition Memory

Figure 1B. A researcher administering the Fagan Test of Recognition Memory

This allowed the observer to remain out of the infant's sight during testing.

Procedure:

All testing took place at Memorial University in two infant laboratories. Parents were first informed about the tasks and procedures and were asked to complete a consent form. A copy of this form can be seen in the Appendix. The order of presentation of the Fagan test and the object examination task were counterbalanced. These tasks took place in different rooms, with infants given time to accommodate to the surroundings in each room. When infants were calm and alert, testing began. Once completed, parents were thanked for their help and given a certificate noting their child's participation in the project. Parents were then asked to complete the RITQ (Carey & McDevitt, 1978) at home and return it by mail within 1 week of testing. If the questionnaire was not returned in that time, the parent was contacted by phone and reminded.

Object Examination Task

Infant attention was assessed with an *infant controlled* habituation procedure and an object examination task (Oakes & Tellinghuisen, 1994). For this procedure infants were first secured in a plastic child booster seat. Each trial was timed by the experimenter during the procedure using a digital stopwatch. All trials for this task began when the object was placed on the tray of the booster seat. If the infant failed to take the toy from the experimenter at the start of any trial, it was coded as a refusal and a trial time of 0 was recorded. The end of each trial occurred when the infant either looked away from or dropped the toy (or some combination of the two) a total of 4 times. In addition, a look was only counted if it was 1 sec or greater in duration. The task began with habituation trials, in which the same object was repeatedly presented to the child over a series of trials until he or she reached a predetermined decrement in looking time, denoted as the criterion. The criterion was reached when infants completed two consecutive trials at times 50% or less of the previous longest trial. This criterion is called a floating point criterion (see Moss, Colombo, Mitchell & Horowitz, 1988). The term 'floating' is used because the criterion changes to accommodate the longest trial during habituation. The floating point, therefore, controlled for infants who did not show a constant decrement in looking time with increased exposure to a visual stimulus. This procedure was repeated until the infant reached the criterion. Four dishabituation (recovery) trials then followed, in which the infant was given the familiar toy and a novel toy for two trials each in an ABBA or BABA order. The order of the toys presented and whether they were "novel" or "familiar" was counterbalanced across participants. Total times for all trials were recorded at the time of the procedure. However, the entire procedure was video recorded so that total looking time, focussed looking (examining) time, casual looking time, and interobserver reliability assessment durations could be coded at a later time.

Data Coding

Visual Attention:

Infants presented a number of different behaviours during the procedure, including mouthing, banging, looking at and examining the toys, as well as glancing around the room and at the mother or experimenter. Any off-camera actions, such as holding the toy out of camera view while still fixating were not coded by either rater.

Three types of visual attention were coded from the videotape of the object examination task: (1) total looking time, (2) focussed looking (examining) time, and (3) casual looking time. First, the total times each infant spent looking at the object on each habituation and recovery trial were timed. A look commenced with the infant fixating the toy and ended when he or she dropped or looked away from it. Fixations of less than 1 sec were not coded. Second, the total time spent looking at the object on each habituation and recovery trial was coded as either *casual looking* or *examining*, in accordance with Ruff's (1986) definitions. *Examining* was defined as a period of focussed looking or studying of the toy and was accompanied by an intense look on the face, furrowed brow, rotating the toy or exploring various components of the toy with the forefinger. *Casual looking* consisted of all other instances of looking not coded as examining. The total *examining* times for each trial were calculated for all infants, as well as the mean look duration and peak look duration times. *Casual looking* was then calculated by subtracting *examining* time from the total looking time for each trial. Durations of *examining* were easily identified by both the experimenter and an independent coder. Interobserver reliability correlations for visual attention were high, ranging from .94 to 1 for *casual looking (looking)* and .94 to .99 for *examining*.

Oral Exploration:

In addition to visual attention, certain oral behaviours were also coded. These variables were recorded to examine the tendency of young infants to explore new objects *orally* as well as *visually*. In accordance with this, overall *mouthing* time was timed from the videotape for all infants. Furthermore, Ruff and colleagues (Ruff, Saltarelli, Capozzoli, & Dubiner, 1992) have differentiated between *active mouthing* and other types of mouthing. Active mouthing of an object, in contrast to other types of oral behaviour such as sucking, presumably serves an exploratory function. This function is indicated by a decline in active mouthing with increased exposure to the object, just as with visual examining. Therefore, once the infant is habituated to the object, he or she will show little or no active mouthing. Other oral behaviours such as sucking and biting the object do not show the same decline with exposure time. As with Ruff and colleagues (see Ruff et al., 1994), *mouthing* was coded whenever the object came into contact with the infants lips, mouth or tongue. *Mouthing* was then divided into *active mouthing* and *other mouthing* (see Ruff et al., 1994). *Active mouthing* was coded whenever the toys touched the inside or outside of the mouth and were moved around or when the lips or tongue moved around it. *Other mouthing* was not coded but included all other instances of mouthing not considered *active mouthing* such as chewing, biting, and sucking the object.

Finally, the frequencies and durations of *active mouthing* followed by looking and *active mouthing* followed by examining were coded. These were instances where infants engaged in active mouthing, then immediately fixated the toy. According to Ruff et al (1994), fixating the object immediately after active mouthing was an extension of oral exploration, where the infant was alternating oral with visual exploration. This pattern is particularly common in young infants and peaks between 6 and 7 months. As they too indicate exploration, episodes of active mouthing followed by examining or looking also decline with repeated exposure to the object (Ruff et al., 1994). Instances of active mouthing followed immediately by a look away from the toy were not included in these coding schemes. Inter-rater reliability for the durations of mouthing followed by *examining* and mouthing followed by *looking* were calculated. Both of these ratings were very high, with a mean reliability of .99.

Heart Rate

To measure heart rate during the object examination task, electrodes from the *Polar Performance* monitor were placed on the infants chest approximately 11 cm down from each armpit. These electrodes were connected to a transmitter which was placed out of sight of the infant. This then transmitted heart rate data to a wrist watch, also placed out of sight. Infants were given several minutes to adjust to the monitor's presence before the object examination task began. Once the first toy was presented, a button on the watch was pressed to record the beginning of habituation and measurement of heart rate commenced. This button was also pressed at the beginning and end of each trial so that they could be differentiated for analysis. Data was recorded in beats per minute (bpm) on a 5-sec interval by the watch receiver. This data was transferred to a computer after completion of the task, where it was analyzed using software provided by *Polar Performance.* This software program displayed bpm in graphical format for each 5-sec interval during each trial.

The Fagan Test of Recognition Memory

This is a computer administered fixed-trial paired-comparison procedure in which infants are given 10 novelty problems. Each of these novelty problems consist of both *familiarization* trials and *novelty* preference test trials in which infants were shown pairs of photos of human faces. All trials were of fixed length, and were timed by the computer. In addition, the computer was used to record which photo the infant fixated, with the experimenter pressing a key of "1" on the keyboard for a look at the left photo and a key of "2" on the keyboard for a look at the right photo. Key presses were sustained for the entire duration of the look. No key was pressed when the infant looked away from the photos.

The test began with familiarization trials, of which there were two types. For one type of familiarization trial, infants were required to look at a pair of identical faces for a predetermined period of time. For the second type of familiarization trial, infants were shown the two identical faces sequentially, first on the right, then on the left. Once familiarization time expired, the computer signalled the end of the trial with a beep and a novelty preference trial began. There were also two types of novelty preference trials depending on the type of familiarization trial that preceded it. In the case of familiarization trials during which infants were shown pairs of stimuli, a novelty preference trial consisted of the experimenter replacing one of the familiar photos with a novel one. In the case of the second type of familiarization trial during which each stimuli was shown sequentially, a novel face was paired with the familiar one. To control for *side-bias*, (i.e. when an infant looks more to one side than the other), all novel photos were presented on one side, then switched with the familiar photo and presented on the other side. Similar to familiarization trials, the computer signalled the end of each novelty preference trial with a beep. The order of the presentation of photos was the same for all infants.

Once all 10 novelty problems were completed, the proportion of total looking time to the novel and familiar stimuli as well as off-task time for all 10 problems were calculated by the computer. The proportion of total looking times to the novel and familiar stimuli were expressed as percentages. Furthermore, the infants' 'score' on the Fagan was determined by these percentages, with a higher score representing a longer look at the novel stimuli.

Results

Initial analyses of the data did not reveal any main effects or interactions of gender or type of stimuli; therefore, these variables were not entered into the analyses below. Prior to analysis, infants in each age group were designated as short or long lookers based on the median split of their *peak examining* (the longest continuous duration of *examining*) time during the object examination task. In a median split, a group of scores are divided into two sets with one set consisting of scores that fall above the median, and the second set consisting of scores that fall below the median. Although previous studies have differentiated these groups based on differences in *peak total looking* (longest look duration) time, the present study will use the more sensitive measure of *peak examining* which is believed to reflect ongoing information processing (Oakes & Tellinghuisen, 1994;

Ruff et al., 1992; Ruff, 1986). In accordance with this, the medians for *examining* were 25.93 sec for 11-month-olds and 11.57 sec for 6-month-olds. Therefore, infants whose *peak* times were *less* than their respective medians were denoted as short lookers, while those with longer examining times were denoted as long lookers. Therefore, unless otherwise noted, all results regarding looker status that follow are based on short and long lookers classifications using peak *examining* time.

Visual Attention

Total time and number of trials to habituation criterion

The first goal of the present study was to investigate age and individual differences in visual attention using a habituation task. Consequently, a 2 (age: 6-month, 11-month) × 2 (looker: short, long) ANOVA of total habituation time during object examination indicated no significant differences between age and time to habituate. However, there was a significant main effect of looker type ($F(2,41) = 29.75$, $p < .001$), such that long lookers (classified based on peak examining time) took longer to habituate than short lookers. There were no interactions between age and looker type and total time to habituate. In addition, a 2 (age: 6-month, 11-month) × 2 (looker: short, long) ANOVA indicated no significant age differences in the number of trials to criterion. Similarly, a 2 (age: 6-month, 11-month) × 2 (looker: short, long) ANOVA indicated no significant effects of looker type on number of trials to criterion ($F(2,40) = 1.16$, $p = .325$). Although long lookers exhibited a greater mean number of trials to habituate ($M = 5.70$ sec, $SE = .449$) than short lookers ($M = 4.76$ sec, $SE = .439$), this effect was not significant, though it is in the expected direction. What this means is that when classified according to peak look duration during examining, infants who exhibited shorter individual looks took less time but not significantly fewer trials to habituate than infants who fixated the objects for more extended periods of time. These data are shown in Table 1.

Table 1. Mean habituation time (sec), and trials to criterion for 6-month-olds, 11-month-olds, long and short lookers. Standard errors are shown in brackets.

	Group			
	6-month-olds (n=23)	11-month-olds (n=23)	short lookers (n=22)	long lookers (n=20)
Mean habituation time	179.65(12.67)	172.17(14.34)	89.22 (11.14)	192.84 (11.64)*
Mean trials to habituate	5.10(.489)	5.54(.556)	4.76 (.439)	5.70 (.449)

*$p < 0.001$

Casual Looking versus Examining During Habituation

Also in accordance with the first goal of the study, two 2(age: 6-month, 11-month) × 2(looker: short, long) ANOVAS were used to compare amount of casual looking and amount of examining time infants directed at the objects during habituation. These analyses revealed a significant effect of age for *casual looking* ($F(1,35) = 23.25$, $p < .001$), such that 6-month-olds engaged in more *casual looking* than 11-month-olds. A significant main effect of age was also found for *examining* ($F(1,35) = 5.24$, $p = .028$), such that 11-month-olds spent more time *examining* the toys than did the 6-month-olds. These results are displayed in Figure 2. In accordance with these results, there was no significant difference between 6- and 11-month-olds and *overall* looking time. An implication of this is that younger infants' use of casual looking may be replaced by examining as they get older.

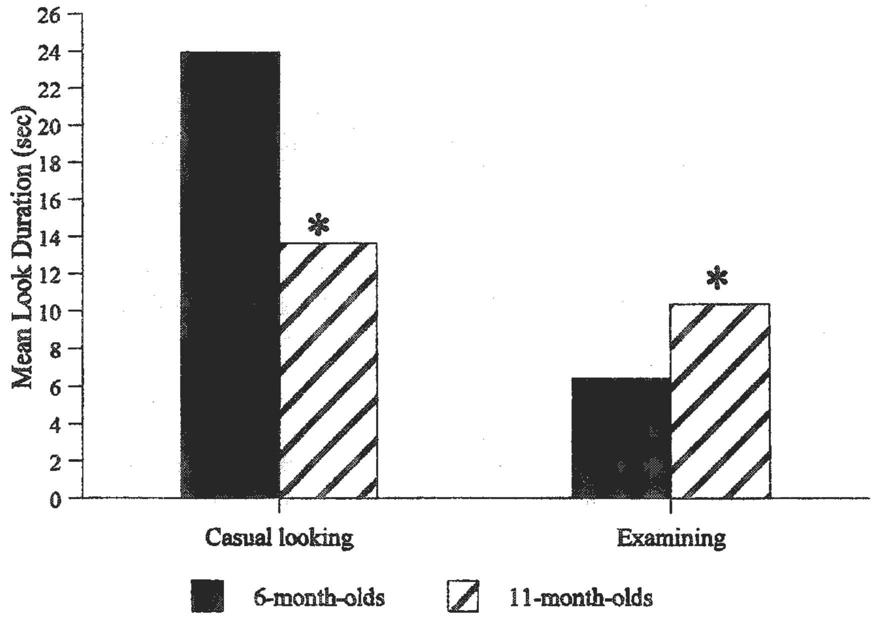

Figure 2. Different forms of attention (casual looking and examining) in 6- and 11-month-olds

There was also a significant main effect of looker type during *casual looking* ($F(1,35) = 8.67$, $p = .006$), whereby long lookers spent more time in *casual looking* than did short lookers. Furthermore, there was a significant main effect of looker type during *examining* ($F(1,35) = 28.96$, $p < .001$), such that long lookers spent more time *examining* the toys than did short lookers. These results are illustrated in Figure 3. There were no interactions between age and looker variables and duration of casual looking or examining.

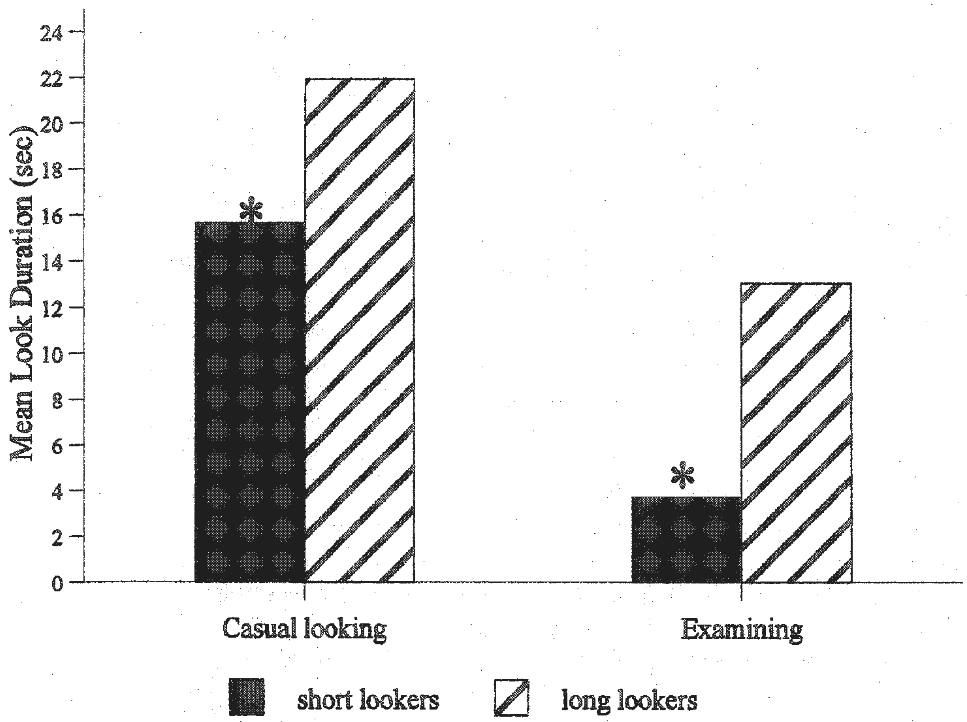

Figure 3. Attentional styles (casual looking and examining) in short and long lookers

Casual Looking versus Examining During Dishabituation or Recovery Trials

A chi-squared analysis revealed that those who were classed as short and long lookers based on peak examining time during habituation were also classified as short and long lookers respectively based on peak examining time during recovery ($\chi^2(2, \underline{N} = 38) = 9.36, p = .009$). There was also a significant correlation between mean casual looking time during habituation and mean casual looking time during recovery ($r(40) = .36, p = .043$). Similarly, mean examining time during habituation and mean examining time during recovery were also significantly correlated ($r(37) = .38$, $p = .034$). This means that when peak *examining* time is used to differentiate infants, those who are the shorter and longer lookers at habituation, retain this classification during dishabituation. In addition, the amount of time infants spent *examining* and *casually looking* generally remained consistent from habituation to dishabituation trials.

There were no significant differences between 6-month-olds and 11-month-olds and examining time during dishabituation (recovery). However, as with habituation trials, a 2(age: 6-month, 11-month) × 2(looker: short, long) ANOVA revealed a significant main effect of age ($F(1,31) = 11.65$, $p = .002$), such that 6-month-olds demonstrated higher *casual looking* times than 11-month-olds. Another 2(age: 6-month, 11-month) × 2(looker: short, long) ANOVA revealed a significant effect of looker type ($F(2,31) = 5.52$, $p = .009$) similar to habituation, such that infants classed as long lookers engaged in more *examining* than short lookers at recovery than long lookers. With regard to *casual looking*, a 2(age: 6-month, 11-month) × 2(looker: short, long) ANOVA indicated no significant differences between short and long lookers and *casual looking* time during the recovery trials. These data can be seen in Table 2. Therefore, older infants engaged in more *examining* than younger infants during habituation trials, but engaged in less *casual looking* than younger infants for both habituation and dishabituation trials. Similarly, infants with longer look durations engaged in more casual looking during habituation, but *examined* more than those with shorter look durations during both habituation and dishabituation.

Table 2. Mean casual looking and examining times (sec) for 6- and 11-month-olds, short and long lookers during dishabituation trials. Standard errors are shown in brackets.

	Group			
	6-month-olds (n=17)	11-month-olds (n=20)	short lookers (n=16)	long lookers (n=18)
Mean casual looking	37.01(4.35)	13.15(5.47)*	17.86(3.76)	23.85(3.54)
Mean examining time	10.52(3.83)	13.58(4.81)	8.67(3.30)	22.49(3.11)*

*$p < 0.01$

As expected, all infants demonstrated significant recovery (dishabituation) to the novel toys during recovery trials. Infants were compared based on their recovery times (casual looking and examining components) to the familiar and novel stimuli at dishabituation (recovery). These data are displayed in Table 3. Paired sample t-tests revealed that both 6- and 11-month-olds recovered to the novel stimulus, as exhibited by a significant increase in casual looking and examining times to the *novel* stimulus during the dishabituation trials. In accordance with this, 6-month-olds engaged in casual looking for a mean time of 17.58 sec (SE = 2.29) to the familiar stimulus and 31.80 sec (SE = 5.38; t(16) = -3.04, p =.008) to the novel stimulus. Similarly, these infants went from a mean examining time of 1.16 sec (SE = .51) for the familiar stimulus, to a mean of 12.30 sec (SE = 3.73; t(16) = -2.92, p =.010) for the novel stimulus. Eleven-month-olds also demonstrated recovery, as their casual looking times increased from 8.21 sec (SE = .85) for the familiar to 13.71 sec (SE = 1.43; t(17) = -3.31, p =.004) for the novel. Their examining times also recovered from 2.67 sec (SE = 1.00) to 18.79 sec (SE = 3.09, t(18) = -5.45, p<.001). As would be expected from infants of this age, infants of both ages were habituated to the familiar stimuli, and were able to discriminate the novel stimulus from the familiar during dishabituation trials.

Table 3. Mean casual looking and examining times (sec) for 6- and 11-month-olds during dishabituation trials. Standard errors are shown in brackets.

	Group	
	6-month-olds (n=17)	11-month-olds (n=19)
Mean casual looking to familiar	17.58(9.45)	8.21(3.72)
Mean casual looking to novel	31.08(5.38)*	13.71(6.23)*
Mean examining time to familiar	1.16(2.12)	2.67(4.36)
Mean examining time to novel	12.30(15.37)*	18.79(13.49)*

*$p < 0.01$

Heart Rate

A 2(age: 6-month, 11-month) × 2(looker: short, long) ANOVA revealed a significant age effect ($F(1,38) = 5.53$, $p = .024$), such that 6-month-olds had a significantly higher mean heart rate than 11-month-olds. The normal mean heart rates for infants at 6-11 months of age is 134 bpm (Alario, 1997), however towards the end of 11 months, and the beginning of 12 months the mean heart rate drops to 119 bpm (Alario, 1997). The mean heart rates for the present study were 139.50 bpm (SE = 2.03) for 6-month-olds and 132.17 bpm (SE = 2.37) for 11-month-olds. Furthermore, a 2(age: 6-month, 11-month) × 2(looker: short, long) ANOVAS indicated no significant differences in heart rate based on looker type.

Because previous research has demonstrated a significant drop in heart rate corresponding to examining time, it was expected that these drops should best be exhibited in the present study on trials with the most examining time. Furthermore, trials with no examining should show no such drops in heart rate. To assess whether there was a significant decrease in heart rate during examining, trials during habituation with the most and least (or no) amount of examining were compared. To do this, the largest drop in heart rate was calculated using the *Polar Performance* software for habituation trials *with* examining and trials *with little or no* examining. These scores were then compared using paired sample t-tests for 6- and 11-month-olds. For 6-month-olds, there was a significant difference between high and low heart rates for trials with the most examining ($t(17) = 9.14$, $p < .001$), whereby heart rate went from a mean of 142.61 bpm (SE = 2.44) to 131.28 bpm (SE = 2.93). Similarly, there was a significant difference between high and low heart rates for 11-month-olds ($t(11) = 13.50$, $p < .001$), who went from a mean heart rate of 136.17 bpm (SE = 1.65)to a mean of 125.08 bpm (SE = 1.58). However it should be noted that there were also significant decreases in heart rate during trials composed of primarily casual looking, and little or no examining for 6-month-olds ($t(17) = 7.99$, p

<.001) and 11-month-olds (t(11) = 6.94, p <.001). Six-month-olds went from a mean of 145.06 bpm (SE = 2.77) to 134.94 bpm (SE = 3.17), and 11-month-olds went from 136.25 bpm (SE = 1.63) to 129.33 bpm (SE= 1.64). Heart rate data is shown in Table 4.

Table 4. Heart rate (HR) data for 6- and 11-month-olds. Standard errors are shown in brackets.

	Group	
Heart Rate (HR) Measure (bpm)	6-month-olds (n=12)	11-month-olds (n=18)
Mean HR	139.50 (2.03)	132.17 (2.37)*
Peak HR during peak examining	142.61(10.37)	136.17(5.72)
Low HR during peak examining	131.28(12.44)	125.08(5.48)**
Peak HR during lowest examining	145.06(11.74)	136.25(5.64)
Low HR during lowest examining	134.94(13.45)	129.33(5.66)**

*$p < 0.05$

**$p < 0.01$

Temperament

Independent t-tests were used to compare short and long lookers on the 9 temperament subscales. Of particular interest were the distractibility and persistence subscales, as these have been found potentially to relate to individual differences in visual attention in previous research. However, there were no significant differences as a function of looker type or age on any of the temperamental subscales of the Revised Infant Temperament Questionnaire. It should be noted that although one of the subscales, rhythmicity, was initially significant, this result was not found once a Bonferroni correction was applied to control for multiple t-tests. Infants scores on the scale fell generally within the normal range for all of the nine subscales. Means for each subscale are presented in Table 5.

Table 5. Carey temperament data for each of the nine subscales for short and long lookers. Standard errors are shown in brackets.

	Group	
	short lookers (n=15)	long lookers (n=15)
Activity level	4.58(.11)	4.44(.12)
Adaptability	2.37(.17)	2.42(.12)
Approach	2.61(.23)	2.74(.15)
Mood	2.80(.17)	2.83(.17)
Intensity	3.83(.10)	3.68(.22)
Distractibility	2.36(.16)	2.30(.13)
Persistence	3.01(.18)	3.16(.22)
Threshold	3.76(.19)	3.88(.19)
Rhythmicity	2.12(.14)	2.66(.21)

Fagan Test of Recognition Memory

The second goal of the study was to determine whether individual differences (short and long looking) in performance on the habituation task predicted performance on the Fagan Test. Consequently, a 2(age: 6-month, 11-month) × 2(looker: short, long) ANOVA comparing the composite novelty preference scores across the 10 novelty problems on the Fagan revealed a significant main effect of looker type ($F(2,41) = 4.93$, p =.012). More specifically, short lookers (M = 64.42 sec, SE = 1.08) scored higher than long lookers (M = 61.34 sec, SE = 1.12). This means that infants who engaged in short look durations during the habituation task also performed superior to those with long look durations on a test of recognition memory. Moreover, this result was only found when short and long looker classifications were based on the median split of peak *examining* time. When infants were classified as long and short lookers according to peak *casual looking* time, a 2(age: 6-month, 11-month) × 2(looker: short, long) ANOVA indicated no significant effect of looker type ($F(1,36) = .005$, $p = .945$). Similarly, when infants were classified as short or long lookers based on peak *overall looking* time, a 2(age: 6-month, 11-month) × 2(looker: short, long) ANOVA indicated no significant effect of looker type ($F(1,43) = .945$, $p = .336$). No significant interaction was found between Fagan score, age, or looker type.

Mouthing During Habituation (Object Examination)

The third goal of this research was to assess non-visual aspects of infants' attention to novel objects. Consequently, four separate 2 (age: 6-month, 11-month) × 2 (looker: short, long) ANOVAS were used to compare infants on overall mouthing time, overall active mouthing time, mouthing time followed by examining, and mouthing time followed by casual looking. Mouthing data can be seen in Figure 4.

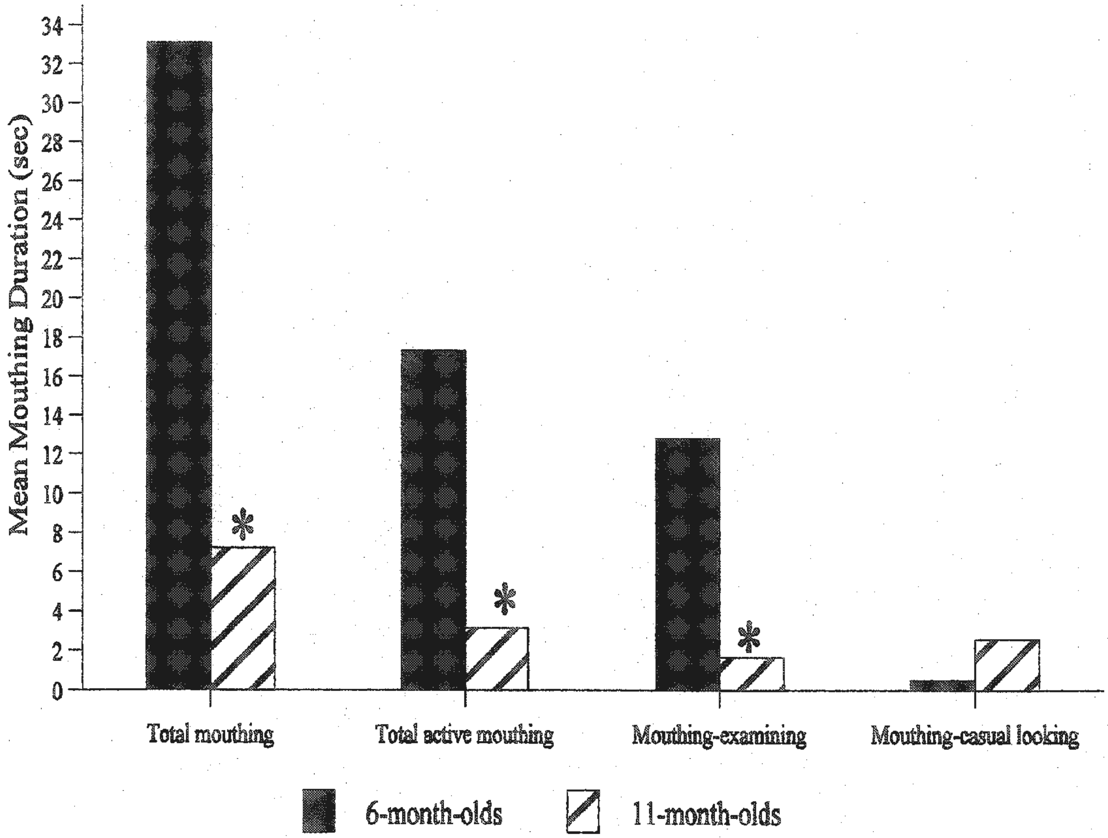

Figure 4. Mouthing variables (total overall, total active, active followed by examining and active followed by casual looking) in 6- and 11-month-olds.

Total Overall Mouthing Time and Total Active Mouthing Time

A series of 2(age: 6-month, 11-month) × 2(looker: short, long) ANOVAS showed that there was a significant main effect of age on total overall mouthing time ($F(1,41) = 5.34$, $p =.026$) and total active mouthing time ($F(1,30) = 5.44$, $p =.027$), such that 6-month-olds exhibited more overall mouthing than 11-month-olds. Furthermore, 6-month-olds engaged in significantly more active mouthing overall than 11-month-olds. In other words, young infants used both visual and oral forms of exploration to investigate the objects. There were no significant main effects or interactions of looker type on any of the mouthing variables.

Total Active Mouthing Time (Followed by Examining or Casual Looking)

Two 2(age: 6-month, 11-month) × 2(looker: short, long) ANOVAS were used to compare total active mouthing time followed by examining and total active mouthing time followed by casual looking. These analyses revealed a significant age effect for active mouthing followed by examining ($F(1,41) = 6.86$, $p = .012$), such that 6-month-olds exhibited significantly more mouthing time followed by examining than 11-month-olds. This is consistent with the previous findings, as the younger infants engaged in significantly more overall mouthing and active mouthing than the older infants. However, a second 2(age: 6-month, 11-month) × 2(looker: short, long) ANOVA comparing active mouthing followed by casual looking indicated no significant effect of age ($F(1,30) = .761$, $p = .390$), such that both 6- and 11-month-olds exhibited comparable amounts of mouthing followed by casual looking.

Discussion

The present study had three main goals. The first was to investigate age and individual (short versus long looker) differences in visual attention using a task different from that of previous researchers. Consequently, the use of the object examination task revealed age and individual (short versus long looker) differences during habituation.

Furthermore, this was the first study to use *examining* time as a way to classify these individual differences. With regard to heart rate, significant decreases were found during periods of *examining*. However, significant decreases in heart rate were also found during periods of little or no *examining*, which makes any definitive conclusions difficult. In addition, no significant differences between infants were found on any of the temperament subscales. The second goal was to assess whether the individual differences (short versus long lookers) found in the habituation task would predict performance on a test of recognition memory, more specifically the Fagan Test. These individual differences were predictive of performance on the Fagan test, as short lookers exhibited superior performance compared to long lookers. The third goal was to use the object examination task to investigate non-visual measures of attention, namely oral exploration. Significant differences were found using these measures, such that 6-month-olds engaged in more active mouthing than 11-month-olds. These results will be discussed in detail below.

Visual Attention

Age and Individual Differences in Habituation

The finding that 6- and 11–month olds took the same amount of time and number of trials to habituate to the toys did not support the hypothesis that there would be age differences between infants' ability to habituate to the stimuli. Specifically, it was predicted that younger infants should have taken longer to habituate and a greater number of trials to habituate than the older infants. In addition, there is evidence that *complex* stimuli require longer looking times from younger infants (Oakes & Tellinghuisen, 1994).

The stimuli used in this study were quite complex (multicolored and 3-dimensional), and yet no age differences were found.

However, long lookers did take longer to habituate than short lookers. This does provide support for the hypothesis that there are information processing differences between infants categorized as short versus long lookers. More specifically, that short lookers are faster processors than long lookers when categorized using a habituation task. This corresponds with other studies that have demonstrated a difference between the performance of long and short lookers on visual tasks (Courage & Howe, 2001; Jankowski & Rose, 1997; Colombo, 1993; Bronson, 1991; Colombo, Mitchell, Coldren & Freeseman, 1991). However, unlike previous research, these results were obtained using *peak examining* time rather than *peak looking* time to classify short and long lookers. *Examining* time is a more sensitive measure of individual differences, and may indicate ongoing information processing (Ruff, 1986). This study supports this idea, because the superior performance of short lookers on the Fagan test was only significant when they were categorized using *peak examining* time. When short and long looking was categorized using *peak looking* time, this difference was not found. Since the present study classified infants based on this measure of information processing, it implies that the differences between short and long lookers that were found may actually reflect differences in information processing. This conclusion could not be made when short and long lookers were classified based on *total looking* time, though this is also a valid measure of infant visual attention. The limitation with regard to examining time however is that it can only be determined using the object examination task. Other procedures such as the paired-comparison task cannot make this distinction because they do not employ 3-dimensional manipulable objects.

<u>Examining versus Casual Looking During Habituation</u>

Further investigation into age and individual differences in visual attention also revealed differences in casual looking and examining time during habituation. Of the time spent looking at the stimuli, the 6-month-olds exhibited more casual attention than the 11-month-olds. The 11-month-olds, in contrast, examined more than the 6-month-olds. What this means is that although both groups may be looking at the stimuli for the same overall amount of time, the components of that overall time vary with age. More specifically, total overall looking for younger infants is believed to be primarily composed of casual looking, while for older infants total overall looking may tend to be composed of focussed attention, in the form of sustained attention. This is consistent with Colombo et al (Colombo, Richman, Shaddy, Greenhoot & Maikranz, 2001) who found that the *proportion* of total looking time accounted for by *sustained attention* increases with age. In addition, the finding in the present study that 6-month-olds engaged in less examining is in accordance with Oakes and Tellinghuisen's (1994) argument that examining is a more mature form of visual attention. These data indicate that there are indeed age differences present, contrary to what was found with the overall habituation time and trials to habituation. This may be because these more generalized measures of habituation are not sensitive enough to detect these differences.

Similar to the age differences found, there were also individual differences between long and short lookers with regard to examining and casual looking during habituation. Long lookers spent more time in casual looking and examining than short lookers. This is not surprising given that long lookers engage in more *overall* looking than short lookers. It should be noted however, that both *examining* and *short looking* are believed to be more mature behaviours than *casual looking* and *long looking* respectively. It is puzzling then that long lookers engaged in more *examining*. If examining was simply a more mature behaviour, short lookers should have engaged in more than long lookers. It may be the case however, that short lookers require less overall looking time, including less examining time than long lookers. Furthermore, individual differences in look duration (e.g. short versus long lookers) appeared to be independent from age, as no interaction was found between these two variables. This finding is inconsistent with the view that long looking is a sign of less mature behaviour, indicative of younger infants and those with developmental delay (Cohen, 1982) and preterm, low birth weight infants (Rose, Feldman, & Jankowski, 2001). This is however, the first study that has attempted to relate individual differences in look duration (short versus long lookers) to attentional components (casual looking versus examining). More research needs to be done to further assess the possible connection between short and long looking and examining and casual attention.

Examining versus Casual Looking During Recovery

Regardless of age or looker status, infants were able to discriminate between the old and new toys at test. In addition, the results regarding examining and casual looking during recovery are comparable to what was found during habituation. More specifically, 6-month-olds exhibited a higher amount of casual looking than 11-month-olds. However, there were no differences in examining with age during recovery. Also similar to habituation, long lookers engaged in more examining than short lookers during test trials. Unlike habituation however, there were no age differences in casual attention during recovery.

Changes in Heart Rate

The present study aimed to replicate the findings of Richards and colleagues (Richards & Hunter, 2002; Lansink, Mintz & Richards, 2000; Richards, 2000; Richards & Cronise, 2000; Lansink & Richards, 1997; Richards & Casey, 1992; Richards & Cameron, 1989; Richards, 1989a,b; Casey & Richards, 1988; Richards, 1987) regarding heart rate changes and examining using a different instrument. This attempt was not successful. It is likely that the measure of beats per minute used in the present study was not sensitive enough to detect changes in heart rate that correspond with examining. Although significant declines in heart rate were found in trials with examining, this result was also found in trials with no examining. This should not have been the case, as trials with no examining should not have contained any significant drop in heart rate. Although *mean* heart rate on these trials may have been a more appropriate measure than *peak* heart rate, the *Polar* equipment did not provide this information. In addition, the use of 'inter-beat interval' as the measure rather than beats per minute may have yielded different results.

However, the instrument used in this study was an accurate measure of heart rate, as the mean heart rates obtained for both groups fit with established normal heart rates for those ages.

Temperamental Differences

It was hypothesized that differences should have existed between long and short looking infants based on temperament. In particular, the subscales of persistance (ability to stay on-task), and distractibility, were thought to relate directly to individual differences in habituation. Despite the findings of the present study which show no variation in temperament, there is support for the claim that temperamental differences can explain variations in information processing (Miceli, Whitman, Borkowski, Braungart-Rieker, & Mitchell, 1998; Miller, Miceli, Whitman, & Borkowski, 1996; Wachs, Morrow, & Slabach, 1990). More specifically, Wachs et al (1990) found a significant negative correlation between the subscale of persistance on the RITQ and performance on a visual recognition task (1990). In a study of 4-month-olds, Miceli and colleagues also found a relationship between temperament, as measured by the BDI of the Bayley Scales (Bayley, 1969) and visual attention using the paired-comparison task. Similarly, Ruddy (1993) found a correlation between shift rate and temperament in 5-month-olds. Furthermore, studies have suggested that there are temperamental differences between infants who complete visual attention tasks and those who do not (Fagen, Ohr, Singer, & Fleckenstein, 1987; Treiber, 1984).

Although no differences were found between temperament styles in infants in the present study, this result can perhaps be partially explained by the scale that was used. The Carey temperament scale, though widely used and accepted in the assessment of child temperament, is not without problems or criticisms. Foremost of these is the fact that this scale relies on parental report (Mangelsdorf, Schoppe, & Buur, 2000). Although parents may possess the most thorough knowledge of a child's behaviour, they can also be biassed toward presenting their child in an overly positive light (Kagan, 1998). With regard to the present study, even children who the researchers noted were particularly difficult and ultimately eliminated from the analyses were still rated by their parents as positive/average. It is impossible to know whether this was an accurate assessment by the parent.

Further criticism of this scale comes from a factor analysis which assessed its 9 subscales (Sanson, Prior, Garino, & Oberklaid, 1987). This study found that there was considerable redundancy in the subscales, with only rhythmicity and persistance being independent factors. These authors go on to suggest that a shortened form of the scale should be considered, eliminating those factors which show poor internal consistency and replicability (Sanson et al., 1987). In summary, more research is needed to investigate the possible link between visual attention and temperament.

Variations in Processing Speed: Fagan Test of Recognition Memory

The second goal of the study was to determine whether individual differences (short versus long looking) that were found on the habituation task predicted performance on the Fagan Test. This was the case, whereby short lookers performed better on the Fagan Test than long lookers. This finding supports the hypothesis that there are fundamental differences in information processing between infants with short look durations and those with longer look durations. In the case of the Fagan Test, short looking was indicative of faster processing, as those infants were more able to recognize the novel stimuli following a brief familiarization interval than long lookers. However, it is important to note that this was only found when short and long lookers were classified according to *peak examining* time. Furthermore, shorter looking also appears to be indicative of better recognition abilities, including efficient encoding and more thorough scanning of the familiar stimulus. This implies that short lookers will more likely later recognize the familiar stimulus during a novelty test (Courage & Howe, 2001; Jankowski & Rose, 1997; Colombo, 1993; Colombo, Freeseman, & Frick, 1992; Bronson, 1991; Colombo, Mitchell, Coldren & Freeseman, 1991). In addition, although short lookers are taking a shorter amount of time to visually process the stimuli, they are still encoding enough information to recognize it at novelty trials. Short looking then, may indeed be the more efficient means of visual information processing for static stimuli. This is contrary to what has been found in previous research, which claimed that although short lookers were faster processors, they may be trading in speed for accuracy (Orlian & Rose, 1997). More specifically, Orlian and Rose (1997) found that infants who took the time to investigate the stimulus thoroughly (long lookers) were better able to extract detail, making them more likely to discriminate between objects during test trials. The present study however, suggests that short looking infants are able to thoroughly encode stimuli using less familiarization time than long lookers. Further evidence of the superior processing ability of short lookers comes from work by Colombo and colleagues, who have shown that short lookers are more efficient at processing both global and featural details of visual stimuli (Colombo et al., 1991). The difference in performance for short versus long lookers on the Fagan Test in the present study adds to the habituation results reported above, which indicate that these individual differences (long versus short looking) can be generalized to other tasks. This is a new and potentially important finding, because it suggests that looking style generalizes across tasks that require visual attention. In addition, this difference was only found when *peak examining* duration was used to determine looker style, so these differences do appear to reflect actual differences in information processing.

It is also important to note that classifications of long versus short looking, as designated by examining time, were robust from habituation through to recovery trials. Those who were classified as short or long lookers during habituation, tended to keep that classification during recovery. This provides further support for the validity of the short versus long longer distinction.

Variations in Oral Examining

The third goal of the present study was to assess individual differences in a non-visual form of exploration. In accordance with the hypotheses, 6-month-olds engaged in more active mouthing in general and more active mouthing followed by examining than 11-month-olds. This fits with the younger infant's use of oral **and** visual means to explore the environment. Ruff et al. (1992) found similar results with their sample of 5- and 11-

month-olds. They also found an age difference whereby mouthing peaked at 7 months and declined by 11 months. These are important findings which indicate that for young infants, particularly those around 6-7 months of age, there is more to attention than vision. Infants of this age rely on both visual and oral forms of exploration. This conclusion has also been made by Bushnell and Boudreau (1998; 1993) who have found that infants develop their haptic perceptual abilities in phases. Specifically, younger infants, those approximately 3-6 months of age, are becoming more adept at exploring objects using their hands, but also still use their mouths, resulting in 'active mouthing'. Older infants, those around 11-months of age for example, are more efficient in their haptic perceptual abilities (Bushnell and Boudreau, 1998; 1993). These infants rely on their hands more exclusively to explore objects, negating the need to mouth objects. Furthermore, unlike active mouthing followed by *examining*, no age differences were found with regard to active mouthing followed by *casual looking*. This is also an important finding, as it suggests that active mouthing followed by *examining* may be the manifestation of the young infant attempting to combine the skills of oral and visual exploration, a type of transitory process. In contrast to this, active mouthing followed by *casual looking* reflects no such transition, which would explain why no age differences were found for this behaviour.

It was interesting that no individual differences were found with regard to oral examining. More specifically, short and long looking infants did not differ in their use of non-visual means of exploration. This seems to indicate that mouthing behaviour is purely a result of age differences between infants, where young infants in general require both visual and oral means of exploration. In contrast older infants, no matter whether they engage in short or long look durations, use primarily only visual means to gather information from the environment.

Proposed Theoretical Bases of Individual Differences

Although it has been established that individual differences (short versus long lookers) do exist betweeen the visual attention of infants on habituation and paired-comparison tasks, attempts to explain the bases of these differences are varied. One explanation for individual differences during the paired-comparison procedure involves neurological and cognitive mechanisms (Jankowski & Rose, 1997; Colombo, 1993; Colombo, Freeseman, & Frick, 1992; Colombo, Mitchell, Coldren & Freeseman, 1991; for reviews of neurological mechanisms and visual attention, see Colombo, 1995; Johnson, 1997; Hood, 1995; Posner & Petersen, 1990; Richards, 1998). A second explanation is that differences in storage underlie the short versus long looker distinction (Colombo, 1993; McCall, 1994). A third explanation is that ability to disengage fixation may be the cause of individual differences (short and long looking; Colombo, 1993; McCall, 1994). Each of these explanations will be discussed in turn below.

Neurological and Cognitive Variations

The exact mechanism underlying this short and long looker distinction is not known, but Colombo and his colleagues have proposed several hypotheses. Two of these emphasize neurological development and the third emphasizes differences in the functional operation of cognitive systems (Freeseman, Coldren & Frick, 1994; Colombo & Mitchell, 1990). In the case of the first neurological mechanism, Colombo (1995) has proposed that structural differences in the central nervous system (CNS) contribute to the distinction between short and long lookers. Structural differences include more extensive myelination of certain pathways in the CNS of short lookers, which could result in an increase in the speed of neural conduction. The second neurological explanation proposes that short lookers have more mature inhibitory mechanisms whereby they can more effectively terminate fixations to a stimulus when required than long lookers (Frick, Colombo, & Saxon, 1999; McCall, 1994). Alternatively, researchers have suggested that differences in style of information intake might underlie performance differences between long and short lookers. Specifically, long lookers may tend to use more immature methods of processing, such as using local processing, focussing on limited aspects of a stimulus and failing to see the 'whole picture' (Freeseman, Coldren & Frick, 1994). Short lookers may (like adults), engage in global to local processing, such that they perceive the stimulus as a whole, then study its components. Consistent with this, short lookers do seem to use larger and more frequent visual saccades than long lookers, while long lookers seem to scan stimuli less extensively and spend significantly more time studying local parts of the stimuli than short lookers (Colombo, 1993; Bronson 1991). In addition, those labelled as short lookers are better able to recognize degraded forms (geometric figures with missing features) than long lookers, again indicating that they can perceive the object as a whole, rather than as a combination of smaller parts (Frick & Colombo, 1996).

Differences in Recognition Memory

Another mechanism underlying individual differences in visual attention may lie in recognition memory. In simplistic terms, recognition memory has three basic components: encoding, storage and retrieval. Most research has focussed on variations in encoding ability, however it is possible that infants who perform better on these tasks may have more extended storage capacities. More specifically, short lookers have been found to possess better retention over immediate (1 minute) and delayed (1 day, 1 month) intervals than long lookers, indicating that not only do they encode quicker, but that they also retain information longer (Courage & Howe, 2001). However, although differences in storage and retrieval ability may contribute to individual differences on recognition memory tests such as paired-comparisons, the extent to which they determine these differences may still be moderated by encoding ability, or the speed with which they encode visual stimuli. The results of the present study support this idea, as short lookers scored higher on the Fagan test, an indication that they were faster at encoding the stimuli than long lookers.

Ability to Inhibit Response

The third attempt to explain individual differences in visual attention involves the ability to inhibit responses. Moreover, a crucial part of attention is the ability to disengage stimuli once fixated, and to inhibit response to stimuli that have already been encoded. The extent to which an infant can do these things may explain variations in looking time. McCall (1994) argues that short lookers are more efficient at inhibiting attention to a stimulus once it is encoded. More specifically, an infant who is readily able to disengage stimuli will more likely be a short looker than an infant who is not as able to disengage. This is a very plausible theory which may partially account for the findings in the present study. More specifically, short lookers may have been better able to disengage fixation from the objects during habituation than long lookers. This may then explain why short lookers engaged in less *examining* and less *casual looking* than long lookers. Further support for this theory comes from Frick, Colombo and Saxon (1999) who looked at 3 and 4-month-olds' ability to disengage from a visual stimulus. They found that long lookers were slower to shift attention from a central to a peripheral stimulus, thus displaying a longer latency time than short lookers. Furthermore, this ability seems to develop with age, with younger infants showing longer latencies than older infants (Frick et al., 1999). Similar conclusions have been reached by Johnson, Posner and Rothbart (1991) who reported that 4-month-olds were better able to disengage a central stimulus and focus on a peripheral stimulus than 2- or 3-month olds. Colombo and colleagues also found that the ability to disengage fixation from visual stimuli increases with age (Colombo et al., 2001).

Summary and Conclusions

The three goals of this study were fulfilled. First, age and individual differences were investigated using a task different from previous studies. This task was successful in demonstrating differences in the amount of *casual looking* and *examining* exhibited by 6- and 11-month-olds, and long and short lookers. In addition, this study was the first to define long and short lookers based on their *peak examining time.* Differences in attention that were found using this more sensitive measure are informative because *examining* time is believed to reflect ongoing information processing time. Second, individual differences exhibited during the habituation procedure were predictive of performance on the Fagan Test. More specifically, infants who engaged in brief fixations (short lookers), during the object examination task scored higher on the Fagan test than those with longer fixations (long lookers). This indicates that the short and long looker distinction reflects basic differences in visual information processing. Third, a non-visual measure of information gathering (active mouthing) revealed age but not individual differences between infants, with younger infants using both visual and oral means to explore a novel object.

To conclude, this study is an important step towards the refinement of cognitive assessment tools for infants. Whereas traditional assessment has employed the measure of *overall look* duration in visual recognition tasks such as the Fagan Test, new methods need to consider the role of *examining*. This is because differences that exist between infants can be masked if simple *look* duration is used. An example of this comes from the present study, whereby individual differences (short versus long looker) that were found between infants when they were classified according to *examining* duration, were not found when these same infants were classified according to *overall looking* duration. Further research should also be directed towards uncovering the specific neurological mechanisms which underlie these differences. For example, differences in neurological structure, recognition memory, and ability to inhibit responses may all contribute to the age and individual differences that exist between infants. Furthermore, researchers investigating cognitive development must also consider the non-visual ways in which infants explore the environment. It is clear that although visual means appear to the be the primary method of investigation, oral methods are also employed, particularly for younger infants. This finding has clinical implications. More specifically, all behaviors which imply information processing (both visual and non-visual) should be assessed in order to pinpoint any cognitive deficits that may exist in an infant.

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Appendix

Consent form

CONSENT FORM

I agree to allow my child ________________________ to participate in a research project on the development of memory to be conducted at Memorial University of Newfoundland. I understand that my child will view a series of faces and will handle various common toys and that his/her memory for these faces and objects will be assessed. In addition, I understand that my child's heart rate will be measured while he/she handles the toys. I understand that my child will be videotaped and observed during this procedure. I will also fill in a questionnaire regarding my child's temperament. I understand that my child's participation is voluntary, that I will be present during the procedure, and that I may withdraw him/her from the project at any time. Also, I understand that my child's performance will be confidential and that the videotape will contain no identifying information. I understand that it will be kept in a locked filing cabinet, transcribed after the study and later destroyed. I also understand that he/she will not be identified in any published report of the study and that the results of the study will be made available to me upon its completion. If you have any further questions you can contact Dr. Mary Courage, 737-8027 or Head of the Psychology Department, Dr. John Evans, 737-8496.

Date: _______________ Parent's name(please print)________________________

Signed:______________________________