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EFFECTS OF STIMULUS MOVEMENT AND POST-HABITUATION DELAY ON NEWBORN INFANTS' ABILITY TO RETAIN VISUAL INFORMATION

by

David P. Laplante

B.A. Hon. McGill University, 1989

M.A. University of Windsor, 1992

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ABSTRACT

The present study was designed to determine whether delayed recognition memory for visual stimuli was present at birth. It was hypothesized that: (1) newborns would demonstrate delayed recognition memory for both a rotating and stationary Maltese Cross (MC); stimulus movement would influence retention; and (3) various patterns of habituation (c.f., Bornstein & Benasich, 1986) would be observed.

Seventy-eight newborns were divided into five delay conditions (0 s, 30 s, 60 s, 90 s, 120 s). Half were habituated to a stationary MC and half to a rotating MC. Following habituation and the delay period, the "habituated" MC was re-presented for 3 trials. The MC was then modified (i.e., i) direction of rotation was reversed; or ii) from stationary to rotating) and presented for 3 trials. Measures of stimulus-directed looking and negative state were recorded.

The results indicated that newborns in the 90 s and 120 s delay conditions displayed significant increases in looking during the first test trial, but not when looking was averaged across the three test trials. Stimulus movement did not influence retention. Newborns in all five delay conditions increased looking to the modified MC. Finally, the majority of newborns exhibited a fluctuating pattern of habituation, but the patterns did not influence retention.

The findings indicate that newborns retain visual information for at least 120 s. However, retrieval appears to degrade after 60 s. Following the longer delay intervals, the first test trial appeared to prime the newborns' long-term memory, permitting successful matching of the "habituated" MC on subsequent trials. Thus, it was concluded that delayed recognition memory for visual stimuli is present at birth.

It was argued that the information processing model provides the best explanation for the obtained findings. Behavioural fatigue was ruled out since newborn looking increased to novelty. Furthermore, variable patterns of looking during the habituation phase (i.e., fluctuating) which were present in some newborns was used to argue against a selective receptor model of newborn habituation. The failure to obtain the expected stimulus movement effects was discussed in terms of procedural considerations.

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A project like this can only be accomplished when a group of individuals work together. I was fortunate to have been surrounded by individuals, who like me believed that the goal - memory at birth - was worthy of their time and effort. To those I recognize by name below, and to the many others who have crossed my path, I give my heartfelt thanks.

First and foremost I must thank the Department of Psychology, in particular its past head, Dr. R. Robert Orr, and the Natural Sciences and Engineering Research Council of Canada (NSERC) for seeing enough potential of this research to fund it. Dr. Orr saw the promise of my research when I first came to the university and came up with the necessary monies to construct the visual chamber. I thank NSREC for funding the study - in the form of a doctoral scholarship.

The document has my name attached to it, but in reality it was developed and written by a committee - my doctoral committee: Drs. R. Robert Orr, Sharon M. McMahon (Nursing), Gedimas Namikas, and E. Glenn Schellenberg.

Special thanks goes to Dr. Orr, for as my supervisor he allowed me to pursue my interests in babies at the same time assuring that my research did not consume me. Bob turned my ideas about the visual processing abilities of newborns into a highly organized and profitable, research plan. My graduation with the degree of Doctor of Philosophy is due largely to his support.

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Data collection, storage, and analyses was aided by a computer program developed by Mark Gross. I also thank Mark for his friendship and frequent use of his "toaster."

The running of newborns was a team effort. In this I was blessed with a highly motivated, creative, and exceptionally talented research team. I sincerely thank

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I am saddened that Grace Hospital will soon be closing its doors. Not only did I collect an enormous amount of data there, it is where my first daughter, Alexie, was born.

A dissertation is more than a simple research project, it is an end to a graduate student's academic life. This is a time for friendships and the exchange of. Thus, I thank Dr. Jerome Cohen for allowing me to blow off steam during the construction of the visual chamber, allowing me into his rat lab, and the all too few and infrequent, but very needed and most enjoyed retreats to wonderful Pelee Island; Katy Dunham for her enormous joy of life, babysitting services, and keeping my feet firmly planted on terra firma; Michael Savage for his wit, love of children - mine included -, and great glove hand; and the Poohs - Brenda Tomini and Mike

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CHAPTER I

Introduction

Human memory has been defined as an active system that receives, stores, organizes, alters, and recovers information about oneself and the world (Baddeley, 1990). According to Crowder (1976), the term "memory" is frequently defined in two different ways: as an entity or as a process. When referring to memory as an entity, the underlying assumption is that there is an alteration of neurons occurring within the cortex that result from learning. Thus, memory as an entity is the hypothesized end result of experience; the existence of such an entity or memory trace is inferred from behaviours (e.g., saying 'cup' to indicate that an object is used for drinking).

Memory as a process, on the other hand, refers to operations required to retain the memory entity over time and to retrieve this information when confronted with other exemplars of the object or message. Hence, the term memory can refer to both the underlying neurological product and the process by which this product is formed (including its development).

For clarity, a distinction between these two facets of memory needs to be made. Accordingly, the term memory trace (Crowder, 1976) will be used when referring to memory as an entity (i.e., the neurological aspect of memory). The term

memory will serve to indicate the process by which the memory trace is developed, retained, and later retrieved.

Ever since Ebbinghaus' (1885/1913) seminal studies of memory functioning in adults, the process of human memory has intrigued psychologists, physiologists, and biologists alike. Nonetheless, very little is known about the memory abilities of newborns. To date, research on memory with newborns has been primarily limited to demonstrations of habituation and object discrimination (see below). Although, visual habituation may reflect a rudimentary memory system (both in term of memory trace and memory as a process; Bornstein, 1985, 1989a, 1989b; Slater & Morison, 1985), this idea is not universally accepted (Bronson, 1974, 1982; Dannemiller & Banks, 1983, 1986) as an explanation of these findings. It remains unknown whether human newborns are capable of demonstrating delayed recognition memory for visual stimuli, although delayed recognition for auditory stimuli has been shown (Zelazo, Weiss, Randolph, Swain, & Moore, 1987; Swain, Clifton, & Zelazo, 1993).

Accordingly, the present study attempts to address a gap in the existing newborn literature by examining delayed recognition memory for visual stimuli. By assessing the newborn's ability to retain visual information beyond the normal post-habituation intertrial interval, the study should expand our knowledge of habituation as an indicator of memory development. This will be accomplished by

determining whether newborns are capable of demonstrating delayed recognition memory for a visual stimulus (i.e., a high contrast, black-and-white Maltese Cross) by varying the length of the post-habituation period. Finally, it will be determined whether delayed recognition memory for visual stimuli can be enhanced by modifying the stimulus (i.e., by introducing stimulus rotation in the fronto-parallel plane). An influence of stimulus movement may be observed since moving stimuli are preferred over identical stationary stimuli (Slater, Morison, Town, & Rose, 1985) and direction of rotation change is detected (Laplante, Orr, Neville, Vorkapich, & Sasso, in press) at birth.

Measuring Recognition Memory in the Human Newborn

Measuring the memory abilities of human newborns is difficult because these subjects are unable to verbalize what they can remember. Memory abilities are therefore inferred from newborn responses (e.g., usually looking or listening) to carefully selected stimuli. The habituation paradigm is widely used among researchers as a means of assessing memory functioning. The habituation paradigm is based on the following assumptions: (a) a decline in responding to repeated information is indicative of memory trace development (Bornstein, 1989a); (b) preference for novel stimuli is indicative of recognition memory (i.e., the subject is able to utilize their memory trace to compare

incoming information with the trace) (Fagan, 1984; Slater, 1989).

In the habituation paradigm with newborns, a single stimulus (e.g., a high contrast, black-and-white striped pattern) is presented repeatedly until criterion of habituation is obtained. Habituation is defined as a decrement in attention resulting from repeated exposure to a stimulus (Thompson & Spencer, 1966). Habituation is typically calculated arbitrarily as a 50%[1] reduction of initial levels of attention (c.f., Bornstein, 1985; Colombo & Mitchell, 1990; Slater, 1989). It must be remembered, however, that a 50% reduction in stimulus directed attention does not imply that the researcher believes that the subject has developed an internal representation of the experienced stimulus that is 50% complete. In fact, the researcher is unable to ascertain how complete a representation of the stimulus has been formed. Following habituation, the researcher uses one of two novelty test techniques: paired-comparison or dishabituation. These will be summarized in the following sections.

---

[1]I have used a less stringent habituation criterion, namely a 40% reduction of initial attention across three consecutive trials in previous research. This criterion was adopted to reduce the number of newborns who typically fail to complete assessments. Research using this criterion has demonstrated that newborns can discriminate movement direction information (Laplante, Orr, Neville, Vorkapich, & Sasso, in press) and process two stimulus dimensions concurrently (Laplante, 1992).

Paired-comparison test of novelty preference. In the paired-comparison test, the habituated stimulus is presented together with a novel stimulus. Memory functioning is assessed by calculating the amount of time the newborn fixates both stimuli. Recognition memory is assumed if the newborn fixates the novel stimulus significantly more than the habituated stimulus. Novelty preference occurs when the newborn recognizes the habituated stimulus as a previously encountered stimulus, requiring less attention. As such, novelty preference in the paired-comparison post-habituation test is believed to be indicative of memory functioning.

Dishabituation test of novelty preference. Recognition memory in the dishabituation test is assessed either by alternating the presentation of the habituated and novel stimuli, or by presenting half of the newborns with the habituated stimulus and the other half with a novel stimulus and conducting group comparisons. If the novel stimulus is attended to more than the habituated stimulus, it is assumed that newborns were able to remember the habituated stimulus in order to discriminate between the two stimuli. Object discrimination occurs because the newborns are able to compare the novel information with a mental representation of the habituated stimulus. Thus, the newborn must retrieve the memory trace of the habituated stimulus and then compare it with the presently available stimulus. Because the newborn is only able to view one stimulus at any given time,

comparisons must occur between the presented stimulus and a memory trace of a previously viewed stimulus. Hence, this ability to discriminate between stimuli appears to reflect a functional memory system (Bornstein, 1989a).

Delayed Recognition Memory

Delayed recognition memory can be operationally defined as either novelty preference (paired-comparison test) or inattentiveness to a familiar stimulus and preference for a novel stimulus (dishabituation test) after a delay longer than the normal inter-trial interval (i.e., 10 s or less) has elapsed. This ability can be assessed using either of the above post-habituation techniques by simply increasing the intertrial interval between the last trial of habituation and the post-habituation test trials.

The term recognition memory will be used to describe novelty preference tests occurring immediately (i.e., within the normal 10 s inter-trial interval) after criterion of habituation has been obtained. Delayed recognition memory, on the other hand, will be used to describe novelty preference tests preceded by a delay lasting longer than the normal inter-trial interval. The methods by which delayed recognition memory can be inferred are outlined below.

Delayed recognition memory: Paired-comparison procedure. For the paired-comparison test, preference for novelty after the imposed delay would indicate retention of the memory trace. Random looking between stimuli or return

to pre-habituation levels of fixation directed at the habituated stimulus would indicate that the newborn was unable to remember the habituated stimulus. The maximum delay between exposure to the first stimulus and the test stimuli for which novelty preference was obtained can be considered as the upper limit of the newborn's recognition memory ability (Rovee-Collier, 1989).

Delayed recognition memory: Dishabituation procedure. For the habituation-dishabituation procedure, delayed recognition memory can be assessed by presenting the newborn with the habituated stimulus following the delay period. Memory functioning would be indicated by continued disinterest in the stimulus. By contrast, re-interest in the habituated stimulus would indicate that the newborn did not recognize the stimulus. Duration of memory trace retention can be defined as the maximum time interval prior to re-interest (i.e., an increase in visual fixation).

Even though both the paired-comparison and sequential dishabituation tests can be used to measure delayed recognition memory, the present study uses the latter procedure. This decision is based on previous research findings (Laplante et al., in press). Using the sequential procedure it was demonstrated that newborns are capable of discriminating between clockwise and counterclockwise stimulus rotation. Other researchers failed to obtain this result when they used a paired-comparison test (e.g., Slater

et al., 1985). It was determined that the habituation-dishabituation procedure may be more sensitive than the paired-comparison procedure for use with newborns.

Researchers have demonstrated delayed recognition memory for auditory stimuli using habituation-dishabituation procedures, but it has not been used to study delayed recognition memories in newborns.

Delayed Recognition Memory at Birth: Evidence from Auditory Processing

Only two studies have reported clear evidence for delayed recognition memory abilities at birth; neither used visual stimuli. Zelazo et al. (1987) demonstrated short-term retention of auditory information in newborns within a single session. A single word (i.e., `tinder' or `beguile') was presented repeatedly until the newborn: (a) turned toward the source of the word (i.e., stereo speakers located on either side of the newborn's head), (b) turned away from the source of the word, or (c) 30 s elapsed (i.e., the maximum length of each trial). The intertrial interval was 10 s. Sound localization was considered to occur if the newborn turned toward the sound source on three of four consecutive trials within the first 16 habituation phase trials[2]. Habituation was defined as: (a) turning away, or (b) turning neither toward nor away from the sound source on

[2]Newborns failing to orient toward the sound source by Trial 16 were excluded from subsequent analyses.

three consecutive trials. Once criterion of habituation was obtained, delays of 10 s, 55 s, 100 s, or 145 s were imposed, with 10 s being the standard intertrial interval.

Following the delay, the habituated word was re-presented to the newborns for at least six trials and headturning was once again observed. If the newborn re-oriented to the habituated sound during these trials, the sound was repeated until criterion of habituation was obtained for a second time. If the newborn failed to re-orient by the sixth post-delay trial, a novel sound was presented. Regardless of the newborn's re-orienting behaviour during the post-delay period, in the final phase a novel word was presented for nine trials or until criterion of orientation (3 of 4 trials with headturns toward the sound source) was obtained.

Newborns in the 10 s and 55 s delay conditions remained disinterested in the re-presentation of the habituated word. Moreover, these newborns actually turned away from the sound source significantly more than subjects in the longer delay conditions. This behaviour suggests that the newborns remained attentive to the sound source and that they "chose" to turn away. On the other hand, newborns in the 100 s and 145 s delay conditions displayed a renewed interest in the habituated word following the delay. In the final phase, all newborns oriented toward the presentation of the novel word, which was interpreted as word discrimination.

The authors suggested that three explanations could account for the results. First, recovery of attention occurring after 100 s could have been the result of reactivation of previously fatigued neurons. This explanation is favoured by Dannemiller and Banks (1983, 1986). Second, levels of attention during the test of delayed recognition memory could have been mediated by changes in the newborns' state. Third, the obtained results may indicate short-term memory trace development and retention for auditory information over at least 55 s. Zelazo et al. (1987) argued that the third interpretation (i.e., memory trace development and retention) best explained their findings. The receptor fatigue argument could not account for these findings because cortical receptors' refractory periods (periods in which activation is not possible) last on the order of milliseconds (c.f., Bullock, Okland, & Grinnell, 1977; Paintal, 1978; Swadlow & Waxman, 1976; Yeomans, 1990). Both the 10- and 55-second intertrial intervals exceeded these refractory periods. Further, a receptor fatigue argument could not account for the newborns' behaviour (turning away) during the test of recognition memory. By definition, such an explanation could only predict cessation of behaviour (i.e., turning neither toward nor away from the sound source).

The behaviour of the newborns in the 10 s and 55 s conditions also negated the second possible explanation

(recognition memory mediated by state changes), since systematic turning away was indicative of continued attentiveness toward the sound. By contrast, changes in state (e.g., increases in crying or drowsiness) would have produced random headturning. Moreover, a behavioural state-change explanation could not account for the demonstrated increase in orienting toward the novel word during the final test phase, as this explanation would predict continued random headturning behaviour to whatever word was presented.

Zelazo et al. (1987) concluded, therefore, that the memory interpretation provided the best explanation of the obtained results. Newborns in the 10 s and 55 s conditions remained disinterested in the habituated word because this word matched their memory trace. The novelty preference test in the final phase of the procedure was an important component of this study. Its inclusion provided support for the interpretation that failing to orient toward the re-presentation of a word following a delay was indicative of memory functioning and was unrelated to state changes or receptor fatigue.

More recently, Swain et al. (1993) demonstrated 24-hour retention of redundant auditory information. On the first day of testing, newborns were presented with 30 trials of a sound ("tinder" or "beguile") and a delay of 145 seconds was introduced. As with the above study, the newborns

demonstrated renewed interest in the sound (i.e., the post-habituation intertrial interval appeared to have exceeded the newborns delayed recognition memory abilities). On the second day, half the newborns were presented with the same sound as on the first day, the other half were presented with a novel sound. The results indicated that newborns hearing the same sound on the second day attended to the sound less often during the initial 30 trials and, more importantly, remained habituated to the sound after the 145 s delay. Newborns hearing the novel sound on the second day (Group 2) responded after the delay as they did on the first day (i.e., these newborns demonstrated an increase in headturns toward the sound source). Thus, it appears that the newborns can retain a memory trace for a specific, novel sound for at least 24-hours.

Considered jointly, these studies suggest that newborns are capable of developing a memory trace for auditory information that has been presented repeatedly. However, the evidence for delayed recognition memory for auditory information does not necessarily imply similar memory functioning for visual information. The present study provides a first attempt to assess delayed recognition memory for visual stimuli at birth. Moreover, determining whether newborns are capable of delayed recognition memory (and possibly the duration of such memories within a single testing session) can help lower the age at which delayed

recognition memory is first seen for visual events (e.g., Bushnell, McCutcheon, Sinclair, & Tweedlie, 1984) and conjugate-reinforced foot kicking (e.g., Rovee-Collier, 1989, 1995). Thus, the present study can begin to determine whether the delayed recognition memory abilities of newborns are quantitatively or qualitatively different from those observed in infants 5 weeks of age and older.

Because the focus of the present study is to determine whether delayed recognition memory for visual stimuli can be demonstrated at birth, a review of the literature outlining memory functioning for visual stimuli is appropriate. First, the literature discussing the earliest age at which delayed recognition memory has been demonstrated will be reviewed. Second, studies of newborns that have demonstrated object discrimination are reviewed because these studies have been used to infer memory abilities.

Neonatal Preference for the Mother's Face

Research on neonatal face recognition indicates that newborns prefer their mothers' faces over those of strangers (Bushnell, Sai, & Mullin, 1985; Walton, Bower, & Bower, 1992). Preference for the mothers' faces following separation suggest memory functioning, but methodological problems weaken this interpretation. For example, Bushnell et al. (1985) used long side-by-side presentations of the mother's and stranger's faces in which facial expressions were not controlled. It is possible that mothers were

better able to elicit and maintain their child's attention by modifying their facial expression, either consciously or subconsciously. Thus, preference may be related to the ability to elicit and maintain attention, a process not requiring delayed recognition memory.

Walton et al. (1992) controlled for this methodological shortcoming by presenting videotaped side-by-side presentations of the mother's and stranger's face. Neonatal preference for the mother's face was observed. However, no preference for the father's face was obtained. Failure to observe preference for the father's face (even though the father was previously seen by the neonates) suggests that something other than delayed recognition memory may be involved. The authors suggested that preference for the mother's face may be the result of a biological process similar to imprinting seen in other species; neonates' first sustained fixation is typically directed at their mother's face.

Neonatal preference for their mother's face provides some support for the position that newborns are capable of maintaining memories for visually experienced events. Nevertheless, the failure to demonstrate preferences for other experienced visual events (e.g., father's face) and methodological problems with the early work make it impossible to draw firm conclusions concerning the newborn's ability to retain visual information. Delayed recognition

of previously unexperienced events is required before firm conclusions can be made.

Delayed Recognition Memory for Visual Stimuli in Infants below 4-Months

Bushnell et al. (1984) demonstrated delayed recognition memory for colour and form in 5- and 9-week-old infants. In their procedure, mothers presented an object to their infants at home for two 15-minute sessions each day for a two week period. The object was then removed from the home and the infants' delayed recognition memories were assessed following a 24-hour delay. Using an infant-controlled, paired-comparison procedure, the duration of first fixations were recorded for the familiar object and a stimulus containing both colour and shape modifications. The results indicated that all infants, regardless of age, looked longer at the novel stimulus. Thus, infants as young as 5 weeks are capable of retaining visual information for a period of 24 hours following extensive habituation training.

The study by Bushnell et al. (1984) provides the earliest evidence for delayed recognition memory abilities for visual stimuli. Yet, this study does not address whether delayed recognition memory can be demonstrated within a single session. To date, delayed recognition memory for visual stimuli in infants this young has only been demonstrated following extensive training. Moreover, as noted above, researchers have yet to demonstrate delayed

recognition memory abilities in the newborn. Evidence for visual memory functioning has been inferred, however, from object discrimination tasks. While providing some evidence for memory trace development, the actual duration of these memory traces in newborns is unknown.

Newborn Visual Habituation at Birth: Implications for Memory Functioning

Newborns have been shown to habituate to repeated presentations of visual stimuli. These findings have been used to provide evidence for memory development (both as memory trace and process) at birth (Slater, 1989). Bornstein (1985, 1988, 1989a) believes habituation of visual attention (measured as a decline in visual fixations) reflects memory trace development (Bornstein, 1985, 1988, 1989a). Moreover, Bornstein (1989a), Slater (1988), and Zelazo (1988b) have independently argued that recovery of visual attention to a novel visual stimulus occurs because of a mismatch between the habituated and novel stimuli, which would require a memory trace of the habituated stimulus.

Empirical evidence. The following provides a very brief account of some discrimination tasks newborns can perform. Researchers have demonstrated recognition memory using a variety of discrimination tasks. Newborns can detect differences between: (a) vertical and horizontal striped line patterns (Laplante, 1992; Slater & Sykes,

1977); (b) diagonal striped line patterns (Braddick, Wattam-Bell, & Atkinson, 1986; Orr, Neville, Vorkapich, & Sasso, 1994; Slater, Morison, & Somers, 1988); (c) checkerboard patterns (Friedman, 1972; Friedman, Bruno, & Vietze, 1974; Friedman & Carpenter, 1971; Friedman, Nagy, & Carpenter, 1970); (d) circles and crosses (Slater, Morison, & Rose, 1982, 1983); (e) rates of stimulus rotation (Slater et al., 1985); (f) direction of stimulus movement (Laplante, 1992; Laplante et al., in press; Neville, Laplante, Vorkapich, & Orr, 1995), (g) visual compounds (Slater, Mattock, Brown, Burnham, & Young, 1991), and (h) multiple stimulus dimensions (Laplante, Orr, Vorkapich, & Neville, submitted). Collectively, these studies provide strong support for the position that newborns are capable of making visual discriminations. Moreover, the consensus among these authors is that these visual discriminations demonstrate a functional memory system in newborns.

Delayed Recognition Memory: General Conclusions

The Zelazo et al. (1987) and Swain et al. (1993) studies clearly indicate that delayed recognition memory for auditory stimuli is present at birth. The visual discrimination studies cited above also suggest memory functioning is present at birth. Yet, documented evidence of delayed recognition memory for visual objects is first seen only at 5 weeks of age. Delayed recognition memory for visual objects at birth remains to be demonstrated.

The lack of research demonstrating delayed recognition memory for visual stimuli at birth, however, may be associated with the choice of stimuli normally used. For example, the majority of studies conducted with newborns have relied on static visual stimuli. While these stimuli may be adequate to assess object discrimination, they may not be sufficiently compelling to assess individual differences in delayed recognition memory at birth. Maximizing the newborn's attention to visual stimuli may therefore enhance memory trace development, thereby increasing delayed recognition abilities. A means for enhancing the newborn infant's attention toward visual stimuli is proposed below in the section on stimulus movement perception.

Stimulus Movement Perception and Memory Functioning in the Human Newborn

Stimulus movement has been shown to facilitate object discrimination (Ruff, 1982) and is viewed as an effective means of attracting and sustaining the attention of 5-month-old infants (Aslin & Shea, 1990). The introduction of stimulus movement into the study of newborn memory trace development (i.e., habituation) and retention may, therefore, enhance delayed recognition memory by increasing stimulus directed attention.

Movement discrimination abilities. From birth, infants prefer to fixate moving over identical stationary objects

(Burnham & Day, 1979; McKenzie & Day, 1976; Slater et al., 1985; Volkman & Dobson, 1976). Volkman and Dobson (1976) have also shown that 4-month-old infants recognize differences between various speeds of movement, with older infants preferring the more rapid rates of stimulus oscillation. In a study conducted by Slater et al. (1985), however, newborns fixated a Maltese Cross rotating at a constant rate of 90°/s significantly more than an identical Maltese Cross rotating at 120°/s.

Preferential fixations based on rotation rate indicates that infants perceive movement at birth and prefer a slower rotation. Laplante and Orr (1994b) also reported that translatory stimulus movement (i.e., stimulus travelled laterally or vertically across the newborns' visual field) increases the onset of novelty detection. These researchers suggested that stimulus movement may increase the attention-getting (Cohen, 1973) properties of visual stimuli. Finally, Laplante et al. (in press) have demonstrated that newborns are capable of detecting changes in the direction of stimulus movement, discriminating between clockwise and counterclockwise rotations of a Maltese Cross.

Speed of novelty detection. Laplante and Orr (1994a) demonstrated that novelty detection occurs faster for moving objects. In this study, newborns presented with striped patterns travelling across their visual field detected

changes to the orientation of the stripes during the first post-habituation trial, while newborns viewing the identical stationary pattern required an extra trial to detect the novel orientation. Nonetheless, both groups of newborns noticed that the pattern had been modified. Stimulus movement may therefore increase the speed of novelty detection by better maintaining newborns' attention to objects in their environment. Thus, moving stimuli may be attended to differently after the delays during the test phase. Newborns may also respond dissimilarly to different stimulus movement modifications during the novelty phase.

In the present study, movement changes were used in the same manner as sound changes were used by Zelazo et al. (1987). Changes in stimulus movement (clockwise to counterclockwise; stationary to rotating) were used as a control against a behavioural fatigue explanation of anticipated unresponsiveness during the test phase (c.f., Sophian, 1980). Because the assessment of delayed recognition memory involves re-introducing the habituated stimulus, increased attention to novelty will help confirm that unresponsiveness to the habituated stimulus was not the result of behavioural state changes. Thus, newborn responsiveness to stimulus movement changes is seen as an important control for arguing against state-change explanations of continued habituation following a post-habituation delay.

Theoretical Explanations of Recognition Memory

Two theories of early infant habituation and recovery (i.e., occurring before 4 months of age) have been used to explain recognition memory: information processing and selective receptor adaptation. This study aims to establish which theoretical position is more likely to be valid. From an information processing perspective, failure to respond to a representation of a Maltese Cross after a delay period following habituation would be indicative of memory development and retention of visual stimuli in the human newborn. If it is found that newborns are capable of retaining visual memories beyond periods previously demonstrated, it may be possible to consider, as Aronson and Tronick (1971) already have, that the means by which newborns and older infants process incoming information is governed by the same mechanisms.

An alternative view, in which memory formation plays no role, has been advanced by Dannemiller and Banks (1983, 1986). Briefly, this view states that behavioural habituation, particularly as measured by decreases in visual fixations and subsequent recovery to novel or unfamiliar objects in infants below three-to-four months, is regulated solely by the functional activation of cortical neurons. Behavioural habituation is said to occur as a result of neuronal fatigue. Behavioural recovery occurs when a second set of cortical neurons are excited as a result of the

presentation of the novel or unfamiliar visual object. Hence, behavioural habituation, according to this model, is regulated by the fatigue of cortical neurons alone.

The selective receptor adaptation model of early infant habituation is based upon the construct of neural fatigue. Behavioural response decrements reflect cortical fatigue. As such, behavioural responding and cortical fatigue are negatively correlated and responding declines as cortical fatigue increases.

To state, however, that behavioural habituation occurs solely as the result of neural fatigue at the level of the cortex is an inadequate explanation, as it does not allow for individual variation seen in duration of looking (Colombo, 1993) and patterns of habituation (Bornstein & Benasich, 1986; McCall, 1979). Moreover, Ackles and Karrer (1991) have criticized the selective receptor adaptation model on both physiological and behavioural grounds. From a physiological perspective, Ackles and Karrer argue that Dannemiller and Banks' (1983, 1986) interpretation of Hubel and Wiesel's (e.g., 1959, 1963, 1965) findings was inaccurate. For example, while receptor fatigue can be obtained, it is limited to specific receptive fields within a neuron. When another receptive field of the same neuron is activated, the neuron responds. As such, receptor fatigue, as outlined by Dannemiller and Banks (1983, 1986), cannot apply to observers who are capable of free eye

movement. From a behavioural perspective, Ackles and Karrer argue that evidence of delayed recognition memory for auditory stimuli (as evidenced by a failure to turn toward a familiar sound and/or active turning away from the familiar sound) following delays of 55 s (c.f., Zelazo et al., 1987) cannot be explained strictly on the basis of neural fatigue as the delay far exceeds the refractory period of cortical neurons. Thus, it may be more plausible to suggest that behavioural habituation occurs as the result of the development of a mental representation of experienced objects that is created and stored as a neural substrate (i.e., memory trace) within the cortex. As such, an information processing model allows for greater individual variation in rates and patterns of habituation (Colombo, 1993, 1995; Colombo, Mitchell, Coldren, & Freeseman, 1991; Freeseman, Colombo, & Coldren, 1993).

While an underlying neural component is presumed, the focus of the present study is on explaining the observable behavioural aspects of habituation. The obtained behavioural evidence will be used to ascertain whether an information processing rather than a strict neuronal explanation can be used to describe the recognition abilities of newborns. Based upon arguments outlined below, an information processing explanation of delayed recognition performance can be advanced if, as with the older infants, human newborns demonstrate (through continued "disinterest")

that they recognize the presented object as being familiar after reasonably long delays (e.g., 60 s[3] or longer). If newborns fail to demonstrate stimulus recognition, a noncognitive explanation (i.e., selective receptor adaptation, behavioural fatigue) of delayed recognition performance will need to be considered.

Individual Variation in Habituation to Visual Stimuli

Another potential means of ascertaining whether newborn habituation to visual stimuli is regulated by receptor fatigue or results from cognitive processes is to chart individual patterns of habituation. To this end, Bornstein and Benasich (1986) and McCall (1979) have both systematically studied individual variation in patterns of habituation to visual stimuli in 5- and 10-month-old infants. These researchers agree that looking times do not always follow a continuous and smooth decline between baseline and habituation periods. That is, some infants actually exhibit increases in their looking times during trials occurring between the two criterion periods (i.e., baseline and habituation) of habituation tasks. Thus, visual attention, as measured by looking times, does not always decline in a linear manner as suggested by both information processing (i.e., decline of 50% of initial

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[3]This represents a very conservative delay period. Other researchers (c.f., Slater, Morison, & Rose, 1982) would argue that a much shorter delay period (i.e., 10 s) would be sufficient to refute a strictly physiological explanation of behavioural habituation in the human newborn.

visual attention) and selective receptor adaptation (decline due to receptor fatigue) definitions of habituation.

Bornstein and Benasich (1986) have operationally defined three potential patterns of habituation: "exponential decrease", "increase-decrease", and "fluctuating." Infants displaying exponential decrease patterns show linear decreases in looking from baseline to criterion of habituation. These infants display patterns which are typically described by definitions of habituation (i.e., a drop in looking from the first to final habituation trial). Infants displaying increase-decrease patterns show initial increases in looking followed by a subsequent linear decrease in visual attention until criterion of habituation is obtained. For these infants, looking times are higher during the second and third trial than the first. Infants displaying fluctuating patterns are very inconsistent in their looking behaviour. These infants show at least two shifts in their looking behaviour (i.e., alternate between decreasing and increasing looking times between consecutive trials) in which at least one reversal involves a trial in which looking times are greater than baseline or lower than criterion of habituation. Of the infants assessed by Bornstein and Benasich (1986), 60% displayed an exponential decrease pattern, 10% an increase-decrease pattern, and the remaining 30% a fluctuating pattern.

McCall (1979) also placed 5-month-old infants into three categories based upon their patterns of habituation in terms of when the infants displayed their highest looking time (i.e., trial with the most stimulus-directed looking) within a fixed trial (i.e., stimulus was presented to each infant for six trials) habituation procedure. According to McCall, 44% of infants looked the most on the first trial and then subsequently displayed a smooth, monotonic decrease in looking, 19% looked the most during the fourth trial, and the remaining 25% on the fifth trial. An additional 12% of infants could not be classified into one of the three categories. Thus, both studies demonstrated that while a linear decrease is the norm, alternative patterns of habituation are also observed.

Bornstein and Benasich (1986) also demonstrated that 5- and 10-month-old infants displaying the exponential decrease pattern of habituation processed visual stimuli more efficiently. These infants required less total looking time and fewer trials to obtain criterion of habituation, despite exhibiting baseline looking times similar to those of infants in the remaining two habituation categories. These infants also showed more pronounced habituation slopes. Yet, Bornstein and Benasich (1986) reported that decreased exposure time to the "habituated" stimulus did not interfere with their ability to discriminate a novel object. As with infants in the remaining two categories, infants in the

exponential decrease category displayed increased looking times to the novel object. This finding was not supported by McCall (1979), however. McCall (1979) noted that infants displaying a linear decrease in looking recovered less than infants in his other two categories.

Bornstein and Benasich (1986) concluded that the exponential decrease pattern of habituation was the most efficient means of processing visual stimuli. They also suggested that the fluctuating pattern of habituation may be the most inefficient. In addition, Bornstein and Benasich (1986) speculated that the fluctuating pattern of habituation may be more prevalent in younger infants, less cognitively advanced infants, and in older infants (i.e., 5- and 10-month-old infants) who are presented with highly complex visual stimuli requiring greater cognitive effort. A linear decrease in looking from baseline to criterion of habituation appears to the most efficient means of encoding information (McCall's finding notwithstanding), but not the sole means.

Moveover, it appears that this form of visual processing develops later (i.e., not all 5-month-old infants in Bornstein and Benasich's sample used this form of processing) than the fluctuating pattern. As such, infants vary in the means by which they encode information, but patterns of habituation do not seem to influence post-habituation processing.

These conclusions are interesting in that they are contrary to what a selective receptor adaptation proposes. From this perceptive, a linear decrease in visual fixations would be indicative of receptor fatigue and should be seen more frequently in younger, not older, organisms because their cortical neurons are less developed and more prone to fatigue (Ellingson, Danahy, Nelson, Lathrop, 1967; Pettigrew, 1974). Specifically, newborns would be more likely to display linear decreases in visual fixations than infants 5-months of age.

Extrapolating from Bornstein and Benasich's findings, and coupled with the findings that stimulus-specific sustained attention increases with age (Lécuyer, 1988; Zelazo, Kearsley, & Stack, 1995), it is theorized that newborns should display inefficient patterns of habituation. As only three patterns of habituation are possible (i.e., exponential decrease, increase-decrease, and fluctuating; listed in order of efficiency), newborns are likely to display the least efficient manner, namely the fluctuating. However, this needs to be experimentally confirmed.

The above research clearly demonstrates that newborns are capable of discriminating between familiar and novel objects. Notwithstanding the results of McCall (1979), it appears that the manner in which information is encoded (i.e., patterns of habituation) does not influence discrimination. It appears that efficient stimulus encoding

does not influence discrimination. It remains to determined, however, whether delayed recognition memory is influenced by the efficiency with which stimuli is encoded. This question is addressed in the present study, as outlined in the next section.

The Present Study

As the above research indicates, newborns are capable of forming lasting (i.e., 24 hours) memory traces of auditory information, implying that information processing abilities are present at birth. Concurrent validation from another modality (i.e., the visual system) is lacking. The present research was designed to provide such confirmation by integrating delay intervals similar to those suggested by Zelazo et al. (1987) into the experimental procedure outlined by Laplante (1992). The present study was designed to answer three questions: (1) What is the maximum duration of memory traces for familiar visual stimuli?; (2) Does stimulus movement influence the process of habituation and/or the ability to retain visual information?; and (3) Do the looking patterns during the habituation phase reflect information processing or selective receptor adaptation?

Newborns were presented repeatedly with either a stationary or rotating Maltese Cross until criterion of habituation (defined as a 40% reduction from baseline measures of visual fixation) was obtained. Upon reaching this criterion, delays of 10 s, 30 s, 60 s, 90 s, or 120 s

were imposed. These delay periods were chosen to approximate those used by Zelazo et al. (1987).

These delay periods extended beyond the upper limits of recognition memory abilities for an auditory stimulus when newborns were tested in a single session. As such, the delay intervals of the present study were also expected to exceed the upper limits of the less mature visual system. Following the delay, the "habituated" stimulus was re-presented for three post-delay test trials.

Finally, a novel stimulus was presented for an additional three trials. Novelty was defined as either: (a) a novel direction of rotation (i.e., a change in direction of rotation); or (b) a change from stationary to rotating. A rotation-to-stationary change was not included because newborns display a preference for moving over stationary stimuli (Slater et al., 1985), and because novelty preference for movement changes decrease across post-habituation trials (Laplante et al., in press). Thus, a novelty preference for a stationary stimuli following stimulus rotation may not be observed. The inclusion of the novelty phase is important to demonstrate that evidence for delayed recognition memory is not simply state related. If newborns can form lasting memory traces for stationary or moving visual stimuli, they should remain habituated during the delay periods but should demonstrate response recovery when the novel stimulus is presented.

The introduction of stimulus movement was assumed to have three benefits in the present study. First of all, motion enables infants to perceive and attend to objects more readily, so it should facilitate habituation. Secondly, stimulus movement reduces the number of subjects failing to complete a testing session (Laplante, 1992). Finally, because it does not alter the physical properties of the stimulus, it allows for a clearer interpretation of changes in the newborn's looking behaviour.

Hypothesis I: Newborns will demonstrate delayed recognition for a visual stimulus. Based upon previous research using auditory stimuli (c.f., Zelazo et al., 1987), it was hypothesized that newborns would "recognize" stationary and moving Maltese Crosses following delays. Such recognition would be demonstrated by continuing disinterest (i.e., habituation level visual fixations during test phase) to the Maltese Cross following the delay interval. The duration of the memory trace (i.e., the minimum intertrial interval leading to an increase in looking was expected to be similar to that obtained using auditory stimuli (i.e., 60 s).

Hypothesis II: Stimulus movement (rotation) will have an influence on the newborns' delayed recognition memory for visual stimuli. Based upon on a re-interpretation of data stemming from the present author's work (e.g., Laplante, 1992; Laplante & Orr, 1994b), and because newborns prefer

moving over identical stationary stimuli (Slater et al., 1985), it was hypothesized that the introduction of stimulus rotation would increase initial levels of stimulus directed visual fixations by increasing the attention-getting properties of the stimulus (Cohen, 1973). Consequently, the attention-getting properties of the rotating Maltese Cross were expected to engage the newborns' attention faster, increase initial levels of looking, facilitate the rate and magnitude of habituation, and possibly alter the duration for which visual stimuli were retained.

Hypothesis III: More newborns will display the fluctuating than the increase-decrease and exponential decrease patterns of habituation. Based upon the findings and conclusions of Bornstein & Benasich (1986) and McCall (1979), it was expected that the majority of newborns would display the least sophisticated form of habituation (i.e., fluctuating patterns). Regardless of stimulus movement, newborns were expected to display patterns of habituation involving repeated reversals of looking times (i.e., decreases and increases on consecutive trials) with the looking time of at least one trial exceeding baseline or dropping below criterion of habituation.

Furthermore, it was anticipated that newborns displaying different patterns of habituation would process (i.e., look at) the Maltese Cross differently. Newborns displaying the most efficient form of habituation (i.e.,

exponential decrease) would look at the Maltese Cross less, obtain criterion of habituation faster, and display greater relative habituation than newborns displaying less mature forms of habituation (i.e., increase-decrease and fluctuating). Yet, it was anticipated that the type of pattern of habituation would not influence post-delay dishabituation. It was expected that looking times during the test phase would be equivalent for newborns displaying the three types of patterns of habituation as post-habituation looking would be dependent upon whether a memory trace existed and not the means by which it was developed. Thus, patterns of habituation would not interact with the duration of post-habituation delays to produce significant changes in test phase looking times and whether newborns dishabituate or remain habituated to the re-presentation of the Maltese Cross.

CHAPTER II

Method

Subjects

Eighty, 2- to 3-day-old full-term (M = 50.3 hours, SD = 14.5 hours, Range = 22 - 98 hours) newborns were recruited from the Well-Baby Nursery of the Salvation Army Grace Hospital, Windsor, Ontario. An additional 21 newborns were recruited (14 Stationary; 7 Rotation) but failed to complete the procedures as a result of elevated negative state during the habituation phase[4]. Moreover, one newborn from the 30 s delay condition (Stationary) and one newborn from the 120 s delay condition (Rotation) were also dropped from the sample because of a computer error (i.e., criterion of habituation was incorrectly calculated). These latter subjects were not replaced[5]. Thus, subsequent analyses were based upon the looking times of the remaining 78 newborns.

Newborns assigned to the Neonatal Intensive Care Unit (NICU) were excluded from the sample with the exception of newborns delivered by means of a caesarean-section (hospital policy required that these newborns be placed in the NICU for a 4-hour observation period immediately after birth).

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[4]Newborns were removed from the sample if: (1) their negative state during the habituation phase was 1.5 standard deviations above the sample mean; (2) they could not be soothed (if they began fretting) prior to the test phase: (3) fell asleep prior to the test phase.

[5]The error was discovered after the data collection phase of the dissertation was completed and preliminary analyses were conducted.

Parents (usually the mother) were required to complete a Parental Consent Form (Appendix A) before their infants participated in the study.

Design

The newborns were randomly assigned to one of 10 experimental conditions of eight newborns each. Past research using this procedure (Laplante & Orr, 1994b; Laplante, et al. in press; Neville et al., 1995; Vorkapich, Laplante, Neville, & Orr 1995) failed to find visual information processing abilities that differentiated the sexes, so sex was not considered in the assignment process.

The experimental conditions were defined by the nature of the habituation stimulus and the length of the post-habituation delay (see Table 1 for a detailed description of each condition). The experimental conditions were: rotation (0 s delay), rotation (30 s delay), rotation (60 s delay), rotation (90 s delay), rotation (120 s delay), stationary (0 s delay), stationary (30 s delay), stationary (60 s delay), stationary (90 s delay), stationary (120 s delay). For half of the newborns in each rotation condition, the stimulus rotated clockwise during habituation and test trials but counterclockwise during novelty trials; the other half had counterclockwise (habituation and test trials) followed by clockwise (novelty trials) rotation.

Table 1

Description of the delay conditions with length of delay and direction of rotation (if presented) for the habituation, test, and novelty phases.

Subjects	Delay (s)	Habituation and Test	Novelty
01-04	0	CW	CCW
05-08	0	CCW	CW
09-12	30	CW	CCW
13-16	30	CCW	CW
17-20	60	CW	CCW
21-24	60	CCW	CW
25-28	90	CW	CCW
29-32	90	CCW	CW
33-36	120	CW	CCW
37-40	120	CCW	CW
41-44	0	NONE	CCW
45-48	0	NONE	CW
49-52	30	NONE	CCW
53-56	30	NONE	CW
57-60	60	NONE	CCW
61-64	60	NONE	CW
65-68	90	NONE	CCW
69-72	90	NONE	CW
73-76	120	NONE	CCW
77-80	120	NONE	CW

Note: CW = clockwise
CCW = counterclockwise
NONE = no rotation (stationary)

For newborns in the stationary conditions, the direction of rotation during the novelty trials (clockwise or counterclockwise) was counterbalanced similarly.

Materials

Apparatus. A three-sided visual chamber measuring 71.1 cm wide X 71.1 cm high X 50.0 cm deep was used to present the visual stimulus to the newborns (see Figure 1). The interior of the chamber was painted flat grey so as to not attract the newborn's attention and to provide a neutral and uniform background upon which the visual stimulus was presented. The stimulus was connected to a reversible motor that could rotate it clockwise or counterclockwise at a constant rate of 60°/second.

An interior partition was located 20.0 cm from the rear wall. It contained an opening measuring 24.1 cm wide X 39.1 cm high, which permitted a clear view of the stimulus. This arrangement served two purposes. First, the partition concealed two 20-watt fluorescent tubes that provided even lighting over the entire surface of the rear wall, including the stimulus. Second, a black-out screen was located behind the partition that, when lowered, prevented the newborns from viewing the visual stimulus during intertrial intervals and the delay period (if imposed). The blackout screen was raised and lowered by the coder using a self-locking latch mounted on a gliding track located on the right wall of the visual chamber.

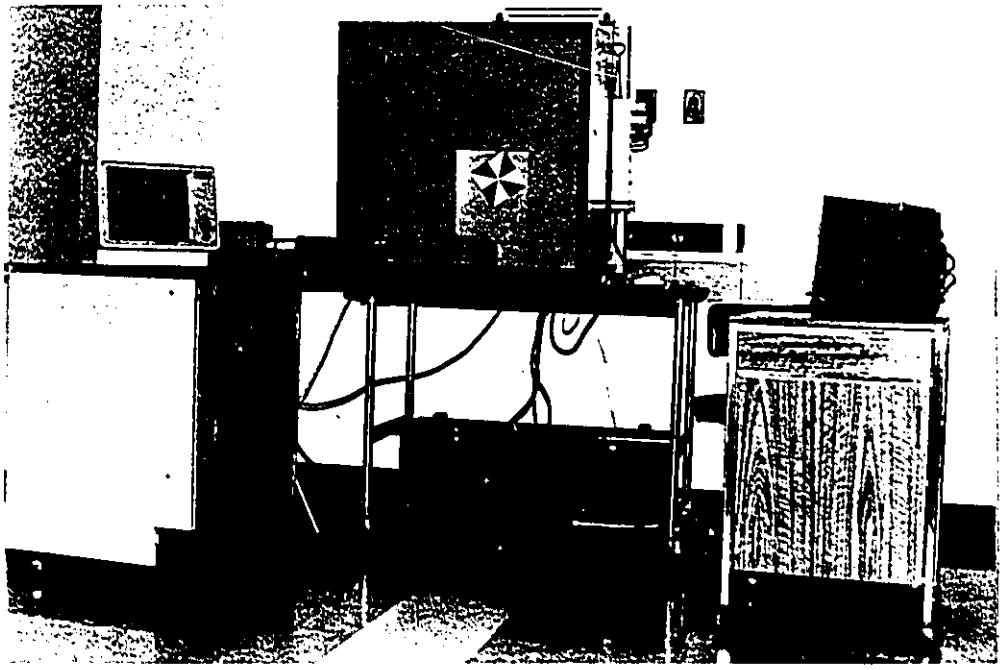

Figure 1. Frontal view of the visual chamber and visual stimulus (i.e., a stylized Maltese Cross) used to assess the delayed recognition memory abilities of newborns.

Running along the base of the interior partition was a baffle (71.1 cm wide X 10.1 cm high X 8.0 cm deep) containing a 10.2 cm opening located equidistant from each sidewall in which a small mirror was located. The mirror was positioned 45° off centre (left edge further away from the newborns) and was angled 4° from vertical (top edge away from the newborns), thus permitting the entire face of the newborns to be captured on a video monitor.

A 7.6 cm circular opening was located in the left, side wall, just behind the front edge of the baffle. A camcorder was positioned in front of this opening and was used to record the faces of the newborns during testing. A black-and-white, 25 cm video monitor was connected to the camcorder, which permitted on-line recording of all behaviours during testing.

Also located to the left side of the viewing chamber was a personal computer. Attached to the computer was a 3-button mouse which was used to record all behaviours (see below) observed during the testing.

Visual stimulus. The visual stimulus was a stylized, black-and-white Maltese Cross (see Figure 1). The stimulus measured 12.7 cm X 12.7 cm and contained a series of eight right-angled triangles (four black and four white). Each triangle measured 6.4 cm along each leg and 9.0 cm along the hypotenuse. When viewed at a distance of 50.0 cm, the visual stimulus subtended a visual angle of 14.3° of the

newborns' visual field with the outer leg of each triangle subtending a visual angle of 7.2°.

The stimulus rotated (if required) clockwise or counterclockwise in the fronto-parallel plane around its midpoint at a constant speed of 60°/s. Hence, a complete 360° rotation took 6 s. Previous research by Laplante et al. (in press) and Neville et al. (1995) demonstrated that newborns habituate to this stimulus and are capable of making discriminations based on direction of rotation.

Computer program. A computer program (Gross, 1992) permitted on-line coding of the newborn infant's behaviours. At the beginning of each trial the observer initiated the coding sequence and recorded the newborn's behaviours for 30 s. After 30 s elapsed (the length of each trial), the program terminated, suspending the observer's ability to record further behaviours. The program emitted two beeps signalling the end of the trial.

In addition, the program determined when the newborns reached criterion of habituation. By using the first three trials as a baseline measure of visual fixation, the program calculated on-line when visual fixation had dropped by 40% (across three consecutive trials beginning with the trial 4). When criterion of habituation was reached, the program signalled that a modification to the visual stimulus was required (if necessary), as indicated by the experimental condition.

Dependent Measures

Three major classes of dependent measures were coded during each trial: `visual fixation,' `fretting,' and `eyes-closed.' Visual fixation was defined as any instance of stimulus-directed gaze that was not associated with negative affect. Instances of visual fixation were recorded by depressing the designated "visual fixation" button on the mouse when the reflection of the Maltese Cross covered 50% of at least one of the newborn's eyes (see Figure 2). The "visual fixation" button was released when the newborns looked away. Total visual fixation was defined as the sum of the durations of all instances of visual fixation during each trial.

Fretting was defined as any instance of negative affective vocalization coupled with the pursing of the mouth and squinting of the eyes. As with visual fixation, instances of fretting were recorded by depressing the designated "fret" button on the mouse. The button was depressed for as long as the newborn fretted. As with the visual fixation measure, the overall duration of fretting was calculated by summing across all instances that occurred per trial.

`Eyes-closed' was defined as any instance in which both of the newborn's eyes were fully closed. As above, all instances of `eyes-closed' were recorded by depressing the

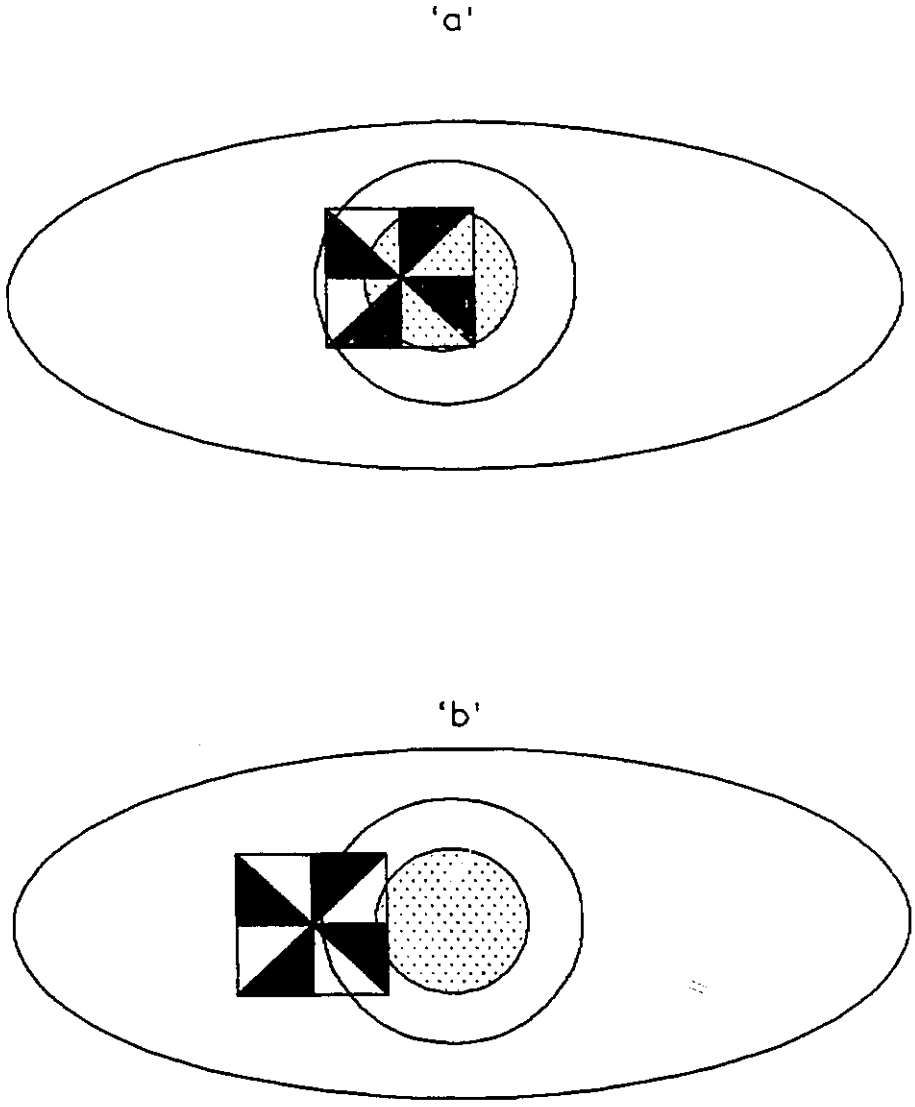

Figure 2. Schematic representation of an example of visual fixation (i.e., stimulus-directed looking) "a" and an example of nonstimulus-directed looking "b".

designated "eyes-closed" button on the mouse for as long as the behaviour persisted. Likewise, the overall amount of `eyes-closed' was calculated in the same manner as the above two measures for each trial.

The above three dependent measures were mutually exclusive assessments of the newborn infant's behaviour. In order to guard against erroneously elevating the newborn's level of visual fixation, measures of fretting and `eyes-closed' took precedence over the visual fixation measure. While the distinction between `eyes-closed' and visual fixation is straightforward (i.e., one cannot fixate a visual stimulus when one's eyes are fully closed), the distinction between fretting and visual fixation is more complex. Fretting usually indicates that the newborn is in a state of general discomfort. It is not always possible, however, to discern the immediate cause for the discomfort. The discomfort might be stimulus related (e.g., boredom) or non-stimulus related (e.g., a result of fatigue, hunger, or a bowel movement). Moreover, it is not always possible to determine whether or not the newborn is actively fixating the stimulus during bouts of fretting. Therefore, any instance of visual fixation during periods of fretting were not recorded.

Reliability. A measure of coder reliability was obtained by having each observer (four observers coded individual newborns during the data collection period)

re-code videotaped assessments of eight newborns from the present study and two from a previous study (Laplante et al., in press). The previous study was included because the same procedure (minus the delay) and stimulus (including rotation) was used. To determine the reliability, 83 trials were re-coded by each observer. The inter-coder correlations were r= 0.89 for visual fixation, r= 0.88 for fretting, and r= 0.89 for eyes closed.

Procedure

An habituation-dishabituation-recovery procedure was used in the present study. All trials were 30 s in duration. The procedure was divided into four phases: habituation, delay, test, and novelty. The testing protocol and a description of each test phase are outlined below.

Testing Protocol. Newborns were brought into a dimly lit testing room located within the Well-Baby Ward, either directly from the parent's rooms or from the day nursery, when they were judged to be in a quiet, alert state (i.e., either immediately before or after they had been fed and always after they had aroused themselves from a sleep). This testing procedure, which differs from the conventional procedure of arousing the newborns from a sleep state approximately one hour after a feeding, has been used previously with success (Laplante, 1992; Laplante et al., in press) and is considered to be less intrusive for parents and medical staff alike.

Once the newborn was in a testable state, one experimenter (holder) positioned the visual stimulus into its proper, habituation phase setting (stationary or rotating, clockwise or counterclockwise) and then held the newborn infant on her lap in front of the viewing chamber so that the newborn's face was centred on the videomonitor. Once the newborn infant was positioned and settled, the second experimenter (observer) then opened the blackout screen and activated the computer program. During the trial, the observer recorded instances of visual fixation, fretting, and `eyes-closed' by depressing the appropriate button on the mouse. At the end of the trial, the computer program automatically terminated and the observer lowered the blackout screen. These steps were repeated until criterion of habituation was obtained. The intertrial interval was approximately 10 s.

A message on the computer monitor informed the holder when criterion of habituation was reached. The holder then informed the observer, except for the 0 s delay conditions for which there was no delay between the habituation and test phase trials. After the delay period, the above steps were repeated for the test and novelty phases trials.

Habituation Phase. During the habituation phase, the visual stimulus was presented to the newborns for a varied number of 30-second trials. In this procedure, the length of the habituation phase was determined by the visual

fixation levels of each individual newborn. The first three trials (baseline) of this phase were used to obtain a baseline measure of visual fixation (amount of time the newborn's gaze was directed at the stimulus) for each newborn infant. The newborn infant was then presented repeatedly with the stimulus until criterion of habituation (defined as a 40% or greater drop relative to baseline) was obtained during three consecutive trials (habituation). Therefore, the minimum number of trials the newborn infant were required to view the habituation phase stimulus was six, with the maximum number of trials being solely determined by each infant. Measures of visual fixation and negative state were recorded during each trial.

Delay Period. After criterion of habituation was obtained, a predetermined delay period was imposed. Depending upon experimental condition, the duration of the delay was 0, 30, 60, 90, or 120 seconds. Each delay period commenced after the intertrial interval had elapsed (approximately 10 s). Hence, the only difference between the final habituation trial and the first test trial was the additional delay before presentations.

Test Phase. After the prescribed delay period, the original "habituation" stimulus was re-presented for three additional trials. As with the habituation phase, measures of visual fixation, fretting, and eyes closed were recorded.

These trials were used to assess whether the newborns recognized the original stimulus.

Novelty Phase. After the three test trials, the visual stimulus was modified by the holder for a final three trials. This phase was included to control for changes in arousal that could have occurred during the test phase.

For experimental conditions involving a rotating stimulus, the direction of rotation was reversed by depressing the appropriate foot pedal (i.e., clockwise to counterclockwise or counterclockwise to clockwise). For experimental conditions involving stationary stimuli, the stimulus was put into motion by depressing on the appropriate foot pedal, with half the newborns being presented with the stimulus rotating clockwise and the remaining half presented with the stimulus rotating counterclockwise. As with the above two phases, measures of visual fixation, fretting, and eyes closed were recorded.

CHAPTER III

Results

Preliminary Analyses

The analyses of mean looking times during the habituation and test phases (i.e., mean of the three trials of each phase) revealed no significant main-effects or interactions. As seen in Table 2, looking was comparable across experimental phases and delay conditions.

Likewise, analyses of mean looking times across the three test trials revealed only a significant Trial main-effect, $F(2, 136) = 3.8$, $p < .03$ (Table 3). Newborns displayed significantly more looking during the first test trial (M = 11.2 s, SD = 8.6 s) relative to the third test trial (M = 8.8 s, SD = 7.8 s). The looking time for the second test trial (M = 9.2 s, SD = 8.3 s) was at an intermediate level between the first and third test trials.

Because nonsignificant differences were obtained when looking was averaged across the three test and habituation phase trials, the remainder of the analyses conducted will focus on looking exhibited during the last habituation phase trial and the first test phase trial. Justification for not presenting the analyses performed using all three test trials comes from Laplante (1992). Laplante demonstrated that newborn dishabituation effects for line orientation and direction of movement changes were limited to the first post-habituation trial.

Table 2

Mean looking (s) averaged across the three trials of the habituation and test phases for newborns in the 0 s, 30 s, 60 s, 90 s, and 120 s delay conditions.

	Looking (s)	
Delay Conditions	Habituation	Test
0 s		
M	10.5	6.5
SD	3.4	3.7
30 s		
M	9.8	8.6
SD	3.4	6.2
60 s		
M	10.9	9.9
SD	3.2	8.2
90 s		
M	10.5	11.8
SD	3.6	6.6
120 s		
M	10.4	11.9
SD	3.6	7.4

Note. The values represent means.

Table 3

Mean looking (s) during the three test trials for newborns in the 0 s, 30 s, 60 s, 90 s, and 120 s delay conditions.

Delay Conditions	Looking (s)		
	Test 1	Test 2	Test 3
0 s			
M	6.3	6.6	6.7
SD	6.1	5.0	5.1
30 s			
M	10.1	7.5	8.1
SD	7.9	8.3	7.8
60 s			
M	12.2	8.7	8.7
SD	9.4	9.3	7.8
90 s			
M	12.2	12.1	11.1
SD	7.9	9.3	9.2
120 s			
M	15.3	11.1	9.4
SD	9.7	8.5	8.3

Note. The values represent means.

Test Phase: Effect of Delay

Mean looking times for newborns in the 0 s, 30 s, 60 s, 90 s, 120 s delay conditions during the last habituation trial and the first test trial are presented in Table 4. To determine whether the length of the post-habituation delay influenced the newborns looking toward the "habituated" Maltese Cross, a 2(Movement Type) X 5(Delay Condition) X 2(Phase, Last Habituation and First Test) analysis of variance (ANOVA) was conducted. This analysis revealed a significant Delay Condition X Phase interaction, $F(4, 68) = 2.64$, $p < .04$.

In order to better understand the interaction, percent relative dishabituation scores were calculated for each newborn (c.f., Colombo, Mitchell, O'Brien, & Horowitz, 1987). Percent relative dishabituation was calculated by dividing the mean looking time for the first test trial by the sum of the mean looking times for the last habituation trial and first test trial and multiplying the outcome by 100 (see equation 1 in Appendix B). A score of 50% represents no change in looking between the last habituation and first test trials. Scores greater than 50% represent an increase in looking during the first test trial relative to the last habituation trial. Finally, scores less than 50% represent a decrease in looking during the first test trial relative to the last habituation trial.

Table 4

Mean Looking (s) during the last habituation trial, first test trial, and first novelty trial for newborns in the 0 s, 30 s, 60 s, 90 s, and 120 s delay conditions.

Delay Conditions	Looking (s)		
	Last Habituation	First Test	First Novelty
0 s			
M	7.9	6.3	11.6
SD	5.3	6.1	9.6
30 s			
M	6.0	10.1	12.8
SD	5.2	7.9	9.3
60 s			
M	8.2	12.2	15.8
SD	6.7	9.4	10.4
90 s			
M	8.0	12.2	18.2
SD	7.3	7.9	9.4
120 s			
M	7.3	15.3	15.1
SD	7.2	9.7	12.5

Note. The values represent means.

A one-way ANOVA revealed a significant main-effect of Delay Condition, $F(4, 73) = 2.80$, $p < .04$ (Figure 3). Four planned Dunnett's tests, contrasting the mean percent relative dishabituation scores of the 0 s delay condition (control) and the remaining four delay conditions, were subsequently performed. The analysis of variance The Dunnett's tests revealed significant mean relative percent dishabituation score differences between the 0 s delay condition (M = 38.9%, SD = 20.0%) and the 90 s (M = 64.2%, SD = 27.5%) and 120 s (M = 67.6%, SD = 27.1%) delay conditions ($ps < .05$).

To corroborate the above finding newborns in the 0 s, 30 s, and 60 s delay conditions and 90 s and 120 s delay conditions were combined to form two groups, one (i.e., 0 s, 30 s, and 60 s, combined) whose looking during the first test trial, as a group, did not differ from the last habituation trial and another (i.e., 90 s and 120 s, combined) whose looking, as a group increased. A Kruskal-Wallis test of independent samples was applied to the percent relative dishabituation scores with the above two groups as the independent variable. The analysis revealed a significant difference in mean rank scores, $H(1) = 7.3$, $p < .007$, indicating that significantly more newborns in the 90 s and 120 s delay conditions (mean rank score = 48.0) displayed increases in their looking during the first test trial relative to the last habituation trial than did

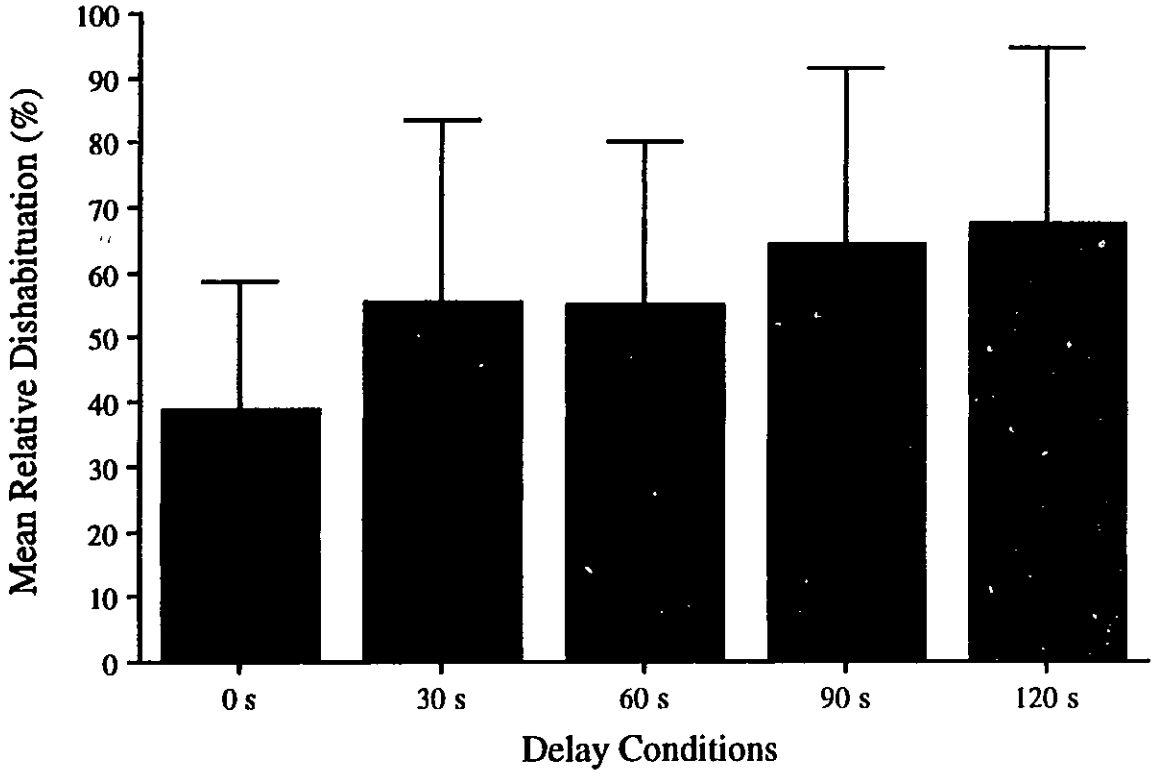

Figure 3. Mean relative dishabituation (%) for newborns in the 0 s, 30 s, 60 s, 90 s, and 120 s delay conditions.

newborns in the shorter delay conditions (mean rank score = 33.9). This result is consistent with that obtained for mean looking, thereby substantiating the prediction that newborns in the 90 s and 120 s delay conditions were more likely to dishabituate to the re-presentation of the Maltese Cross.

Summary of test phase results. Only newborns in the 90 s and 120 s delay conditions displayed higher mean percent relative dishabituation scores for the first test trial than newborns in the control condition (i.e., 0 s). Newborns in the 30 s, and 60 s delay conditions displayed mean percent relative dishabituation scores similar to those of the controls (i.e., 0 s). Also, a greater proportion of newborns in the 90 s and 120 s delay conditions exhibited renewed interest (as measured by direction of change in looking times) in the "habituated" Maltese Cross during the test phase than newborns in the remaining three conditions. Stimulus movement had no influence on the duration of memory traces. Thus, newborns retained visual information for at least 60 seconds and memory traces were not influenced by stimulus movement.

Novelty Phase: A Control

The novelty phase was included as a control for a decline in looking across the experimental phases that may have arisen as a result of increases in behavioural fatigue. Renewed looking to modified versions of the Maltese Cross

during the novelty phase would indicate that the previously obtained test phase results (i.e., newborns in the 0 s, 30 s, and 60 s delay conditions remained habituated) were not caused by increases in behavioural fatigue. Mean looking times for newborns in the 0 s, 30 s, 60 s, 90 s, 120 s delay conditions during the last habituation trial and the first novelty phase trial are presented in Table 4.

In order to determine whether newborns exhibited renewed interested to the modified Maltese Cross, a 2(Movement Type) X 5(Delay Condition) X 2(Phase, Last Habituation trial and First Novelty trial) ANOVA was conducted on the mean looking times of the last habituation trial and the first novelty trial. This analysis revealed a significant main-effect of Phase, $F(1, 68) = 39.4$, $p < .0001$. Overall, newborns in all five delay conditions looked at the Maltese Cross significant more during the first novelty trial (M = 14.7 s, SD = 10.3 s) relative to the last habituation trial (M = 7.5 s, SD = 6.3 s).

The analysis also revealed a nonsignificant Stimulus Movement X Phase interaction, $F(1, 68) = 3.02$, $p = .0868$, (Figure 4) in the anticipated direction. The interaction indicates that newborns presented initially with the stationary Maltese Cross (i.e., Maltese Cross began to rotate during the novelty phase) tended to look more than did newborns initially presented with the rotating Maltese

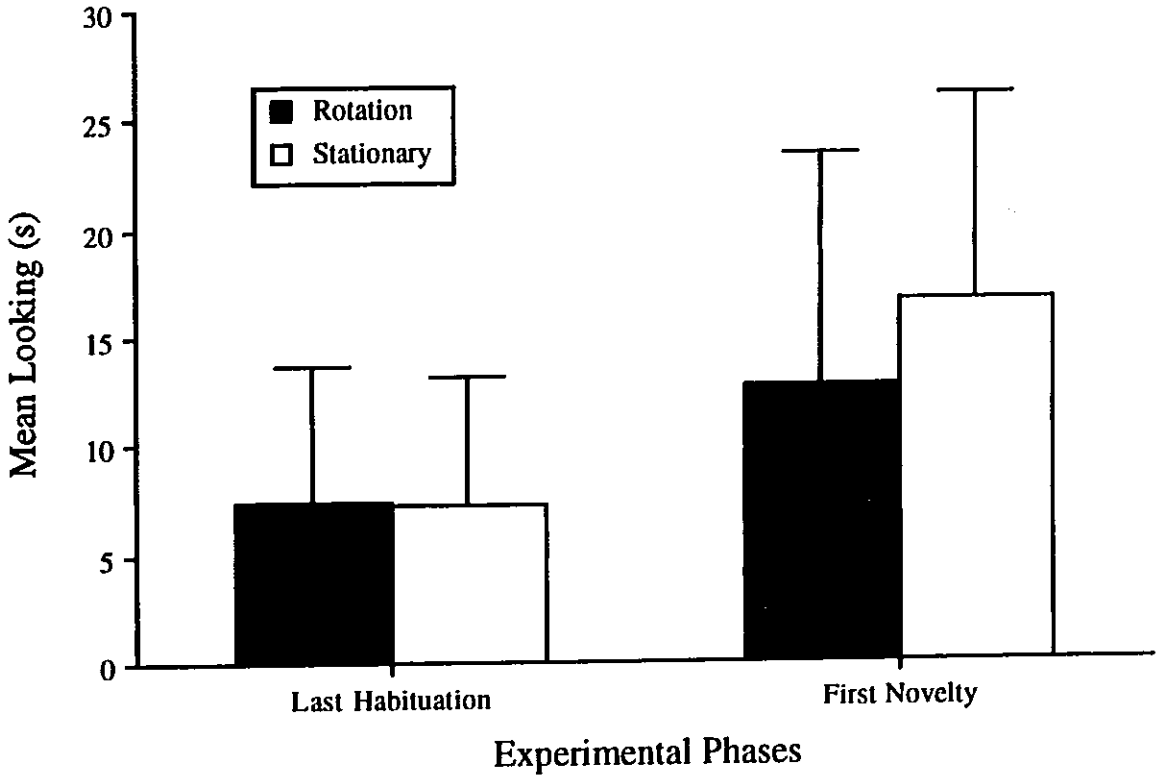

Figure 4. Mean looking (s) during the last habituation trial and the first novelty trial, as a function of movement type.

Cross (i.e., direction of rotation was modified) during the first novelty trial.

Finally, mean latency to first fixation as a function of Movement Type was assessed to determine if a particular movement modification attracted the newborns' attention faster. The analysis revealed that newborns presented with the Maltese Cross that went from stationary to rotating exhibited shorter mean latencies to first fixation in the novelty phase (M = 4.0 s, SD = 5.5 s) relative to newborns initially presented with the rotating Maltese Cross (M = 7.9 s, SD = 10.4 s), $t(76) = 2.1$, $p < .04$. Going from stationary to rotating in the novelty phase appears to have re-attracted the newborns' attention faster than changing the direction of rotation. Increased speed in attending to the now rotating Maltese Cross (as compared to the Maltese Cross which changed direction of rotation) may have been the cause of the previously obtained stimulus movement trend for overall mean looking of the first novelty trial.

Summary of novelty phase results. The results indicate that newborns displayed an increase in looking when the Maltese Crosses was modified. This result indicates that the test phase results are unlikely to be attributable to a general decline in looking across the three experimental phases. Finally, the results indicate that the Maltese Cross going from stationary to rotating was more slightly more compelling (i.e., attracted attention faster) than the

Maltese Cross in which the direction of rotation was reversed.

Habituation Phase

A series of analyses were conducted on several habituation phase measures (i.e., total habituation phase looking, baseline looking, magnitude of habituation, trials to criterion of habituation) to determine if stimulus movement influenced the process of habituation. Moreover, a comparison of the five delay conditions was conducted to determine whether the obtained test trial differences could have resulted from differences in habituation phase looking.

Total habituation phase looking was defined as the sum of all looks between the first baseline trial and the last habituation trial. Baseline looking was defined as the total amount of stimulus-directed fixations during the first three trials of the procedure. Magnitude of habituation represented the percent decrease in looking between baseline and habituation. Trials to criterion of habituation represented the number of trials newborns required to exhibit a 40% or greater decline in looking between baseline and criterion of habituation.

Total habituation phase looking. To determine if differences in total looking during the entire habituation phase (i.e., from the first baseline to the last habituation trial) existed between the five delay conditions, and if stimulus movement influenced total habituation looking, a

5(Delay Condition) X 2(Movement Type) ANOVA was performed. As indicated in Figure 5, looking was comparable across the five delay conditions, $F(4, 68) = 0.6$, and two movement types, $F(1, 68) = 0.1$. Thus, previous test phase results cannot be attributed to unequal total exposure time to the Maltese Cross during the habituation phase.

Baseline: Effect of stimulus movement. In order to determine whether stimulus movement influenced initial levels of stimulus-directed looking, comparisons were conducted on mean length of the first look, mean total baseline looking, and mean latency to first fixation.

A 2(Movement Type) X 3(Trials) ANOVA performed on the mean length of first look revealed a significant main-effect of Movement Type, $F(1, 76) = 4.5$, $p < .04$ (Figure 6). Newborns seeing the rotating Maltese Cross displayed longer first looks than did the other newborns. This result suggests that initial stimulus-directed looks are increased by the introduction of stimulus rotation.

To determine if stimulus movement influenced total stimulus-directed looking during the baseline trials, a 2(Movement Type) X 3(Trials) ANOVA was conducted. This analysis revealed a significant Trial main-effect, $F(2, 152) = 4.8$, $p < .01$ (Figure 7). However, the anticipated Movement Type main-effect and the Movement Type X Trials interaction were not in evidence. Trend analyses were conducted on the mean total looking times for the trials to determine the

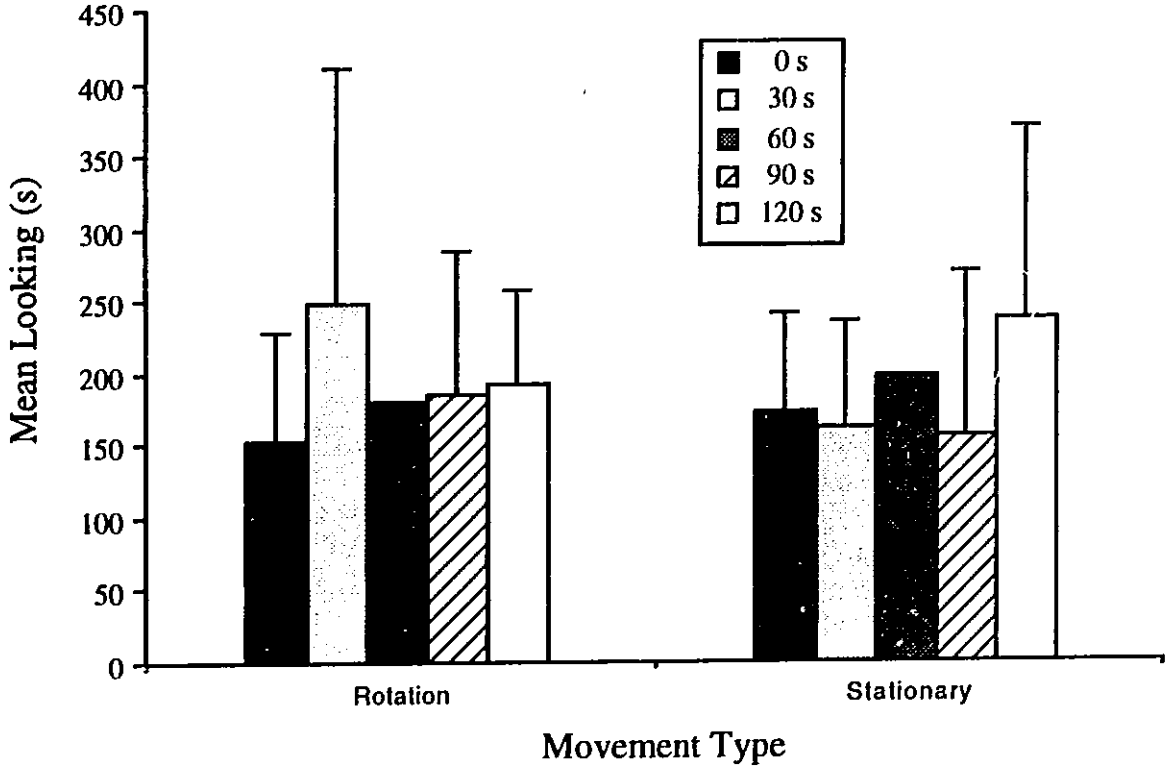

Figure 5. Mean total habituation phase looking (s) for newborns in the 0 s, 30 s, 60 s, 90 s, and 120 s delay conditions, as a function of movement type.

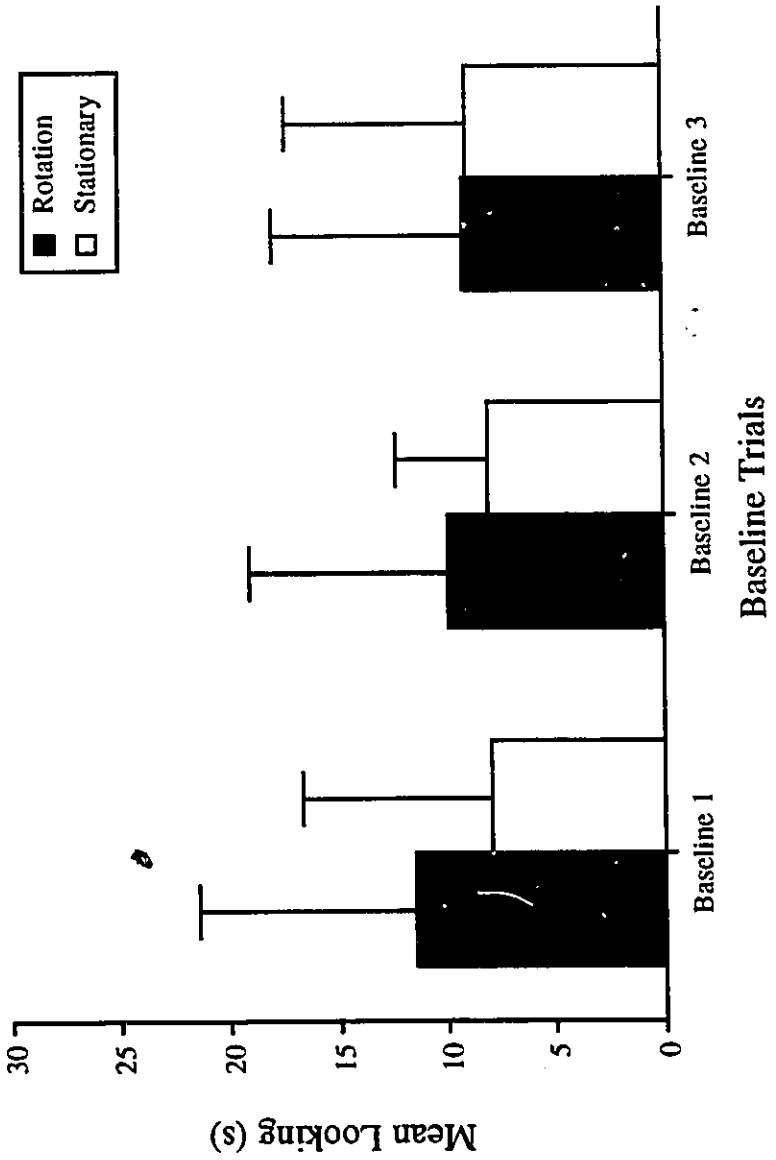

Figure 6. Mean length of first look (s) during the baseline trials, as a function of movement type.

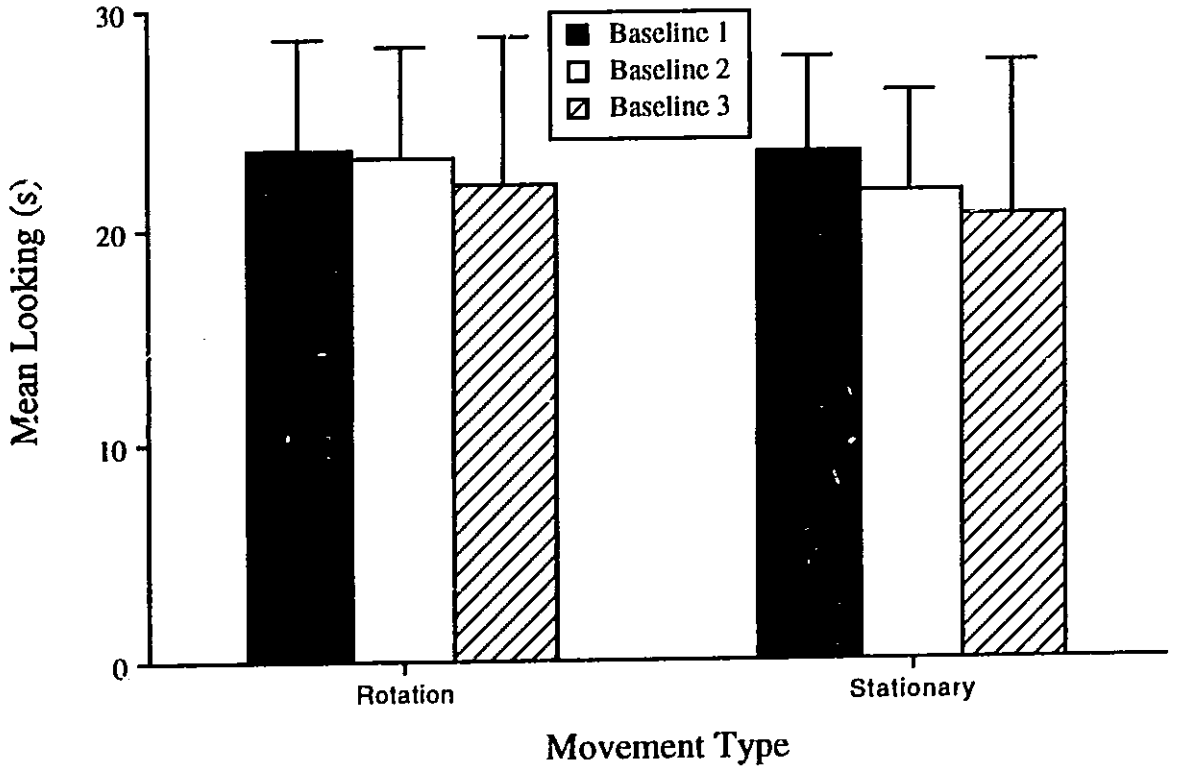

Figure 7. Mean looking (s) during the baseline trials, as a function of movement type.

pattern of looking across the baseline trials. This analysis revealed a significant linear ($F(1, 154) = 9.4$, $p < .01$) trend, but a nonsignificant quadratic ($F(1, 154) = 0.0$) trend. Mean total looking decreased from the first to third baseline trial (First: M = 23.5 s, SD = 4.7 s; Second: M = 22.4 s, SD = 5.3 s; Third: M = 21.3 s, SD = 6.9 s).

The analysis conducted on the mean latency to first fixation revealed no significant Movement Type differences. Newborns seeing the rotating Maltese Cross required, on average, 1.5 s (SD = 1.6 s) to fixate the stimulus. Newborns seeing the stationary Maltese Cross required, on average, 1.8 s (SD = 2.0 s) to fixate the stimulus. Thus, during baseline presentations, the attention-getting properties of the Maltese Cross do not appear to be increased by the introduction of stimulus movement.

Magnitude of habituation. To determine if stimulus movement influenced the magnitude of habituation, percent decline in looking between baseline and criterion of habituation was calculated for each newborn. Percent decline in looking between baseline and habituation was obtained by dividing the mean habituation looking time by the mean baseline looking time and multiplying the outcome by 100 (see equation 2 in Appendix B). A 2(Movement Type) X 5(Delay Condition) ANOVA revealed no significant main-effects or interaction (see Figure 8). This result indicates that stimulus movement did not influence the

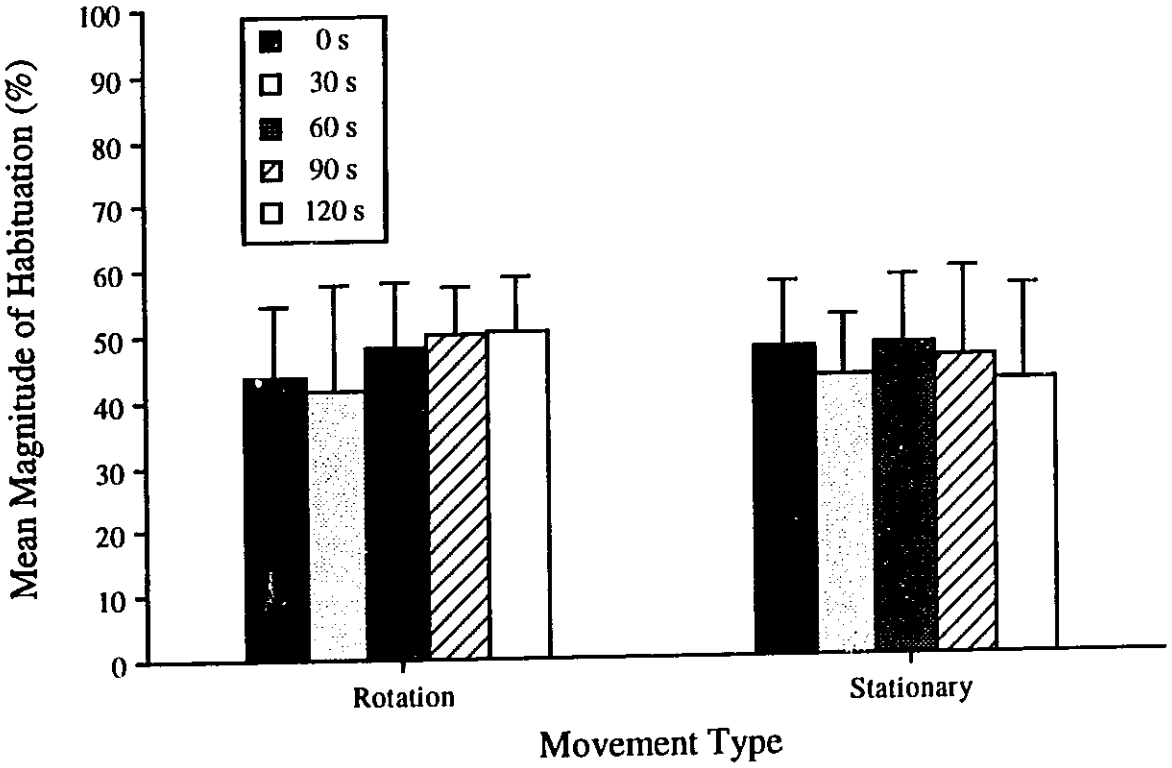

Figure 8. Mean magnitude of habituation (%) for newborns in the 0 s, 30 s, 60 s, 90 s, and 120 s delay conditions, as a function of movement type.

magnitude of habituation. More importantly, differences in magnitude of habituation cannot be used to account for the obtained delay condition differences test phase looking.

Trials to criterion of habituation. In order to determine whether differences in exposure time (i.e., as assessed by number of trials the Maltese Cross was presented to the newborns) to the Maltese Cross during the habituation phase may have accounted for the obtained differences in test phase looking, a 2(Movement Type) X 5(Delay Condition) ANOVA was performed on the number of trials newborns required to obtain criterion of habituation. This analysis revealed no significant main-effects or interactions (Figure 9). The results indicate that, on average, newborns in the 90 s and 120 s delay conditions were not exposed to the Maltese Crosses more frequently than were newborns in the remaining three delay conditions. This result also indicates that newborns presented with the rotating and stationary Maltese Cross did not differ in the number of trials required to obtain criterion of habituation.

Summary of habituation phase results. With the exception of the first stimulus-directed look during each baseline trial, stimulus movement had no influence on the process of habituation. Measures of mean total baseline looking, mean latency to first look, mean magnitude of habituation, and mean trials to criterion of habituation

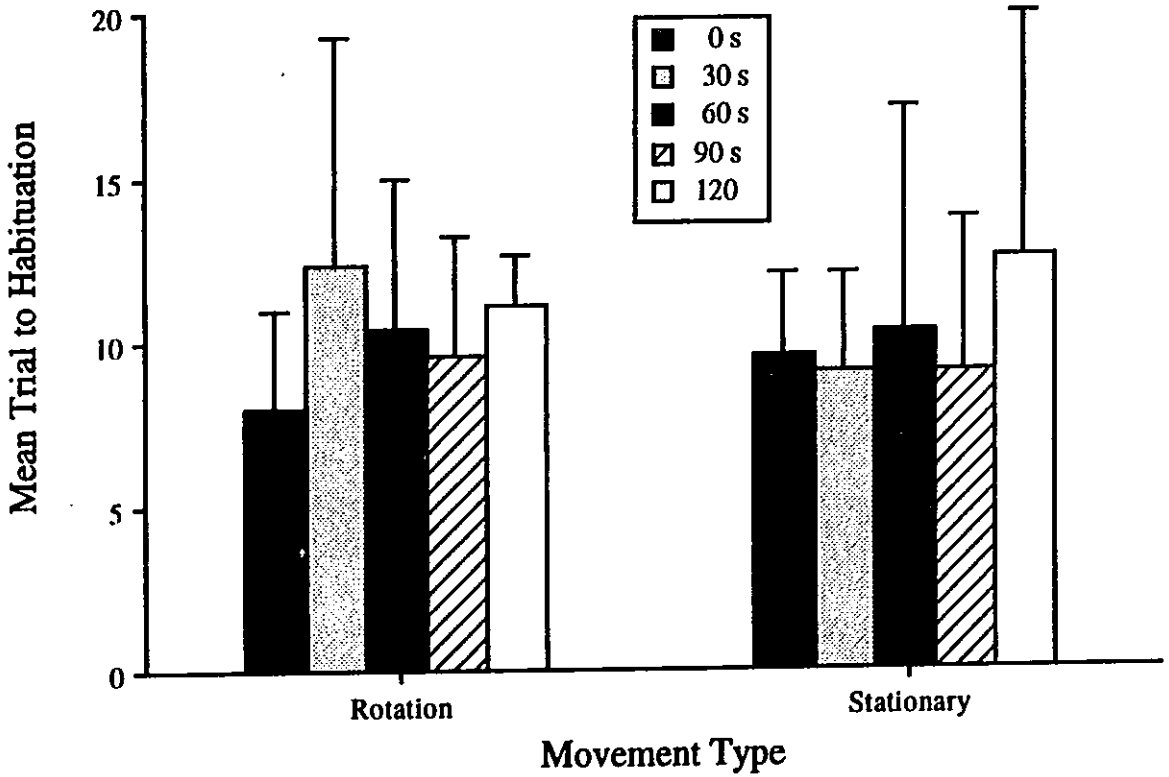

Figure 9. Mean number of trials to criterion of habituation for newborns in the 0 s, 30 s, 60 s, 90 s, and 120 s delay conditions, as a function of movment type.

were similar for newborns seeing the rotating and stationary Maltese Crosses. However, newborns seeing the rotating Maltese Cross did display longer first looks on each of the first three trials. The habituation phase results indicate that newborns in the five delay conditions displayed comparable looking behaviour during this phase of the experiment, suggesting that test phase differences in looking times cannot be attributed to habituation phase looking time differences.

Individual Patterns of Habituation.

Using Bornstein and Benasich (1986) definitions individual patterns of habituation were examined for each newborn using all habituation phase trials. Thirteen newborns displayed fixation patterns best described as exponential decreasing, 7 as increasing-decreasing, and 58 as fluctuating (Table 5). An omnibus chi-square analysis performed on the entire sample revealed an uneven distribution of newborns across the three categories, $\underline{X}^2(2) = 59.8$, $\underline{p} < .001$. Subsequent pairwise chi-square analyses, using Bonferroni corrections, were performed for all possible pairings. Analyses comparing the fluctuating pattern with the exponential decrease and increase-decrease patterns revealed significant differences in subject distribution, $\underline{X}^2(1) = 28.5$, $\underline{p} < .002$ and $\underline{X}^2(1) = 40.0$, $\underline{p} < .002$, respectively. The analysis comparing the exponential decrease and increase-decrease patterns failed to reach

Table 5

Number of newborns displaying exponential decrease, increase-decrease, and fluctuating patterns of habituation.

Patterns of Habituation	Number of Newborns
Exponential Decrease	13
Increase-Decrease	7
Fluctuating	58

significance. Accordingly, more newborns were categorized as displaying fluctuating patterns of habituation.

The patterns of habituation were further divided by stimulus movement (i.e., rotation or stationary). A chi-square analysis performed on this distribution failed to reach significance, $\underline{X}^2(2) = 1.6$ (Table 6). Thus, the distribution of newborns into the three pattern of habituation categories was not independent of stimulus movement.

A series of ANOVAs was conducted on mean baseline looking times, mean total habituation phase looking times, mean magnitude of habituation, and mean trials to criterion of habituation using patterns of habituation as the independent variable. The analyses revealed that the mean baseline looking was similar across the three looking patterns ($\underline{F}(2, 75) = 1.4$) (Table 7). Significant or near significant differences were obtained for mean total habituation phase looking times ($\underline{F}(2, 75) = 4.6$, $\underline{p} < .02$) (Figure 10), mean magnitude of habituation ($\underline{F}(2, 75) = 2.9$, $\underline{p} = .06$) (Figure 11), and mean trials to criterion of habituation ($\underline{F}(2, 75) = 6.4$, $\underline{p} < .003$ (Table 8). Newborns classified as fluctuating looked significantly more at the Maltese Cross and required more trials to obtain criterion of habituation. However, newborns classified as exponential decreasing tended to display more pronounced decreases in

Table 6

Number of newborns displaying exponential decrease, increase-decrease, and fluctuating patterns of habituation, as a function of movement type.

	Stimulus Movement	
Patterns of Habituation	Rotation	Stationary
Exponential Decrease	6	7
Increase-Decrease	2	5
Fluctuating	31	27

Table 7

Mean Looking (s) during baseline for newborns displaying exponential decrease, increase-decrease, and fluctuating patterns of habituation.

Patterns of Habituation	Looking (s)
Exponential Decrease	
M	23.0
SD	4.1
Increase-Decrease	
M	24.7
SD	2.8
Fluctuating	
M	22.0
SD	4.5

Note. The values represent means.

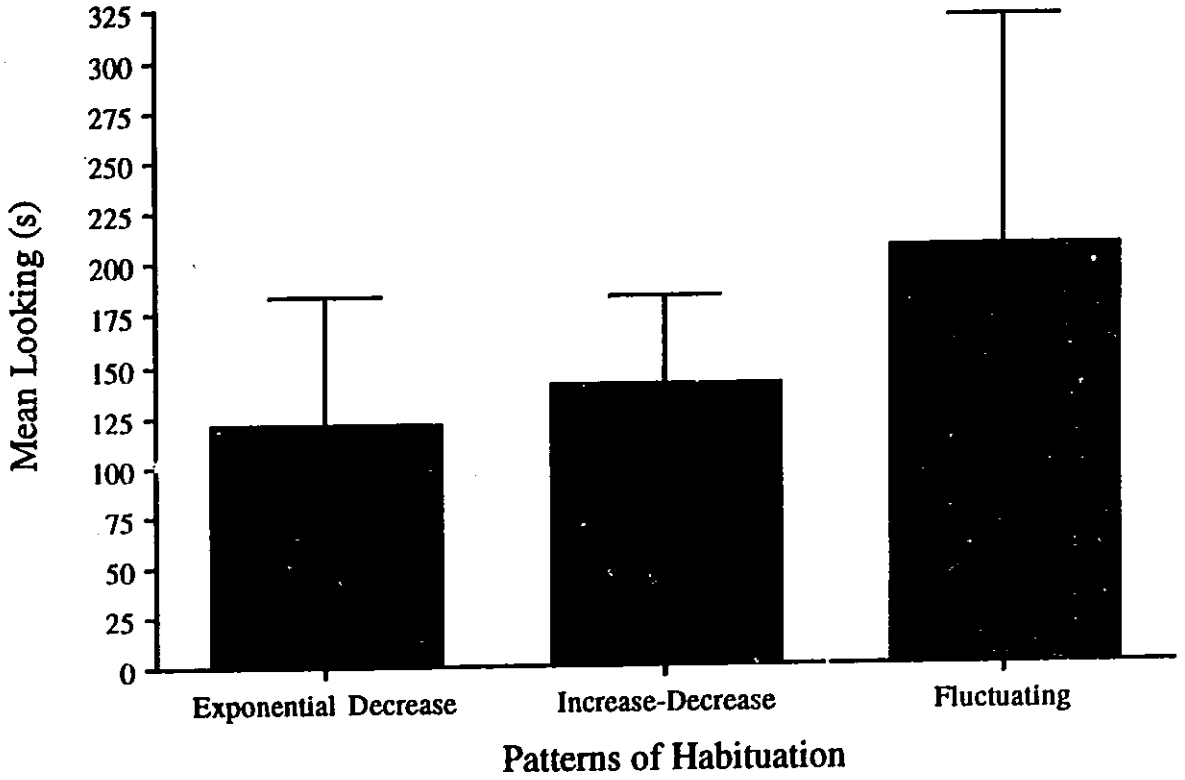

Figure 10. Mean total habituation phase looking (s) for newborns displaying exponential decrease, increase-decrease, and fluctuating patterns of habituation.

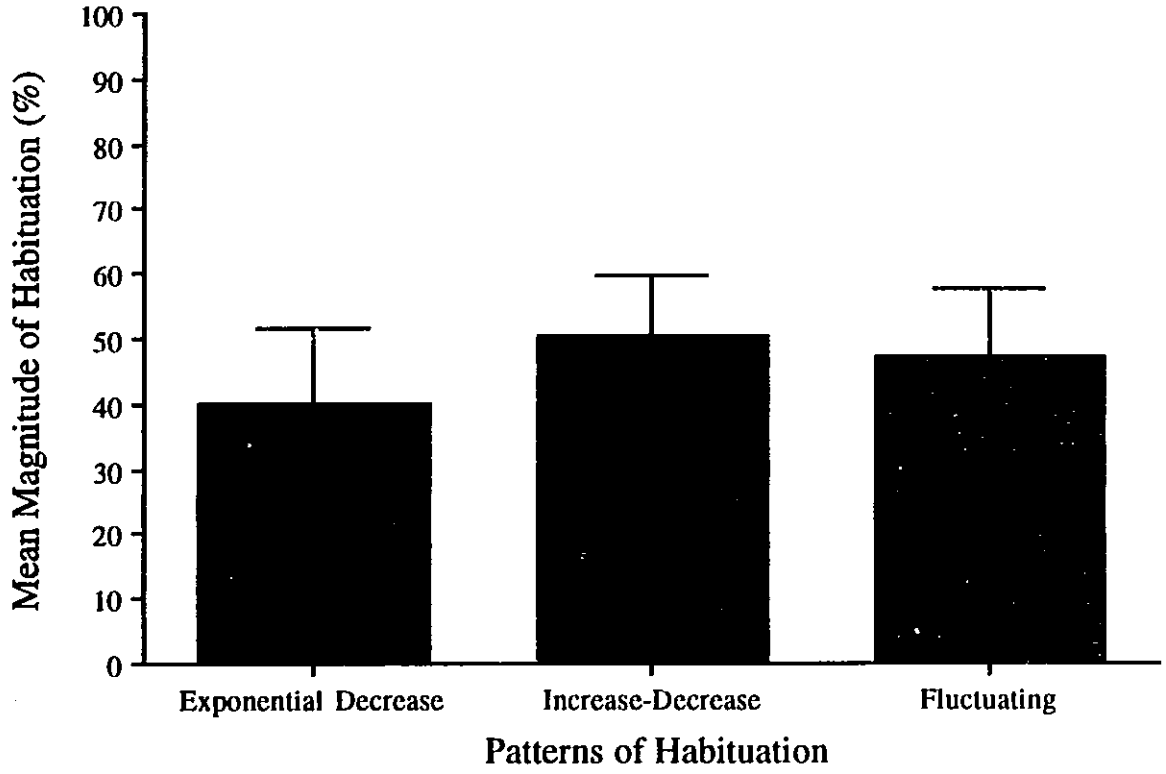

Figure 11. Mean magnitude of habituation (%) for newborns displaying exponential decrease, increase-decrease, and fluctuating patterns of habituation.

Table 8

Mean trials to criterion of habituation for newborns displaying exponential decrease, increase-decrease, and fluctuating habituation patterns.

Patterns of Habituation	Number of Trials
Exponential Decrease	
M	7.0
SD	2.0
Increase-Decrease	
M	7.3
SD	1.6
Fluctuating	
M	11.2
SD	5.0

Note. The values represent means.

looking between baseline and habituation. Thus, differences in mean habituation looking, mean trials to criterion of habituation, and mean magnitude of habituation were related to pattern of habituation, and not to differences in mean baseline looking.

Finally, A Kruskal-Wallis test was applied to the percent relative dishabituation scores using the three pattern of habituation categories as the independent variable. This analysis revealed that the efficiency in which newborns encoded information pertaining to the Maltese Cross did not influence their dishabituation status, $\underline{H}(2) = 5.2$, n.s. Similar numbers of newborns from each pattern of habituation category displayed increases in looking during the first test trial relative to the last habituation trial.

Summary of individual patterns of habituation results. More newborns were classified into the fluctuating pattern of habituation category than into the exponential decrease and increase-decrease categories. This finding supports the hypothesis that newborns are likely to display the least efficient form of visual processing. Newborns classified into the fluctuating pattern of habituation category looked, on average, longer at the Maltese Cross and required, on average, more trials to obtain criterion of habituation. Stimulus movement had no influence on patterns of habituation. As anticipated, pattern of habituation classification had no bearing on test phase looking.

"Habituated" and "dishabituated" newborns were evenly distributed across the three pattern of habituation categories.

Negative State

A measure of negative state was calculated by summing the duration of fretting and eyes-closed for each trial. A 2(Movement Type) X 5(Delay) X 4(Phase; Baseline, Habituation, Test, and Novelty) ANOVA was conducted to compare the mean negative state levels of the newborns during each experimental phase. This analysis revealed a significant Phase main-effect, $F(3, 201) = 31.6$, $p < .0001$ (Figure 12). No other significant main-effects or interactions were observed. A trend analysis performed on negative state revealed a significant linear component, $F(1, 231) = 95.9$, $p < .0001$, but nonsignificant quadratic ($F(1, 231) = 0.14$) and cubic ($F(1, 231) = 0.7$) components. Negative state increased linearly from the baseline to novelty. The results also indicate that increases in negative state did not differ significantly across conditions. Thus, test phase looking differences are not attributable to differences in negative state.

Newborns were subsequently divided into two categories (i.e., Low State and High State) based upon a median split of negative state expressed during the habituation phase. Newborns expressing a mean of 0.34 s of negative state or

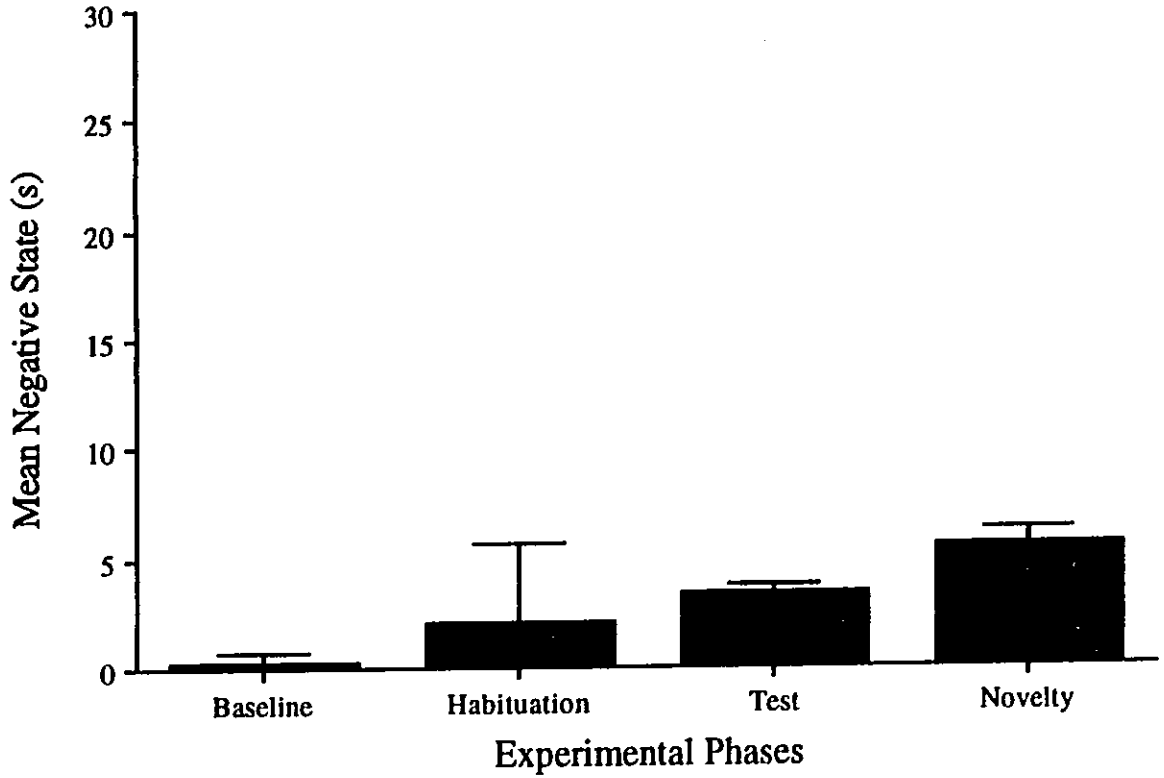

Figure 12. Mean negative state (s) expressed by all newborns during baseline, habituation, test, and novelty phases.

less (range: 0.0 s to 0.34 s) were classified as Low State. Newborns expressing a mean of 0.35 s of negative state or greater (range: 0.35 s to 6.0 s) were classified as High State. A Kruskal-Wallis test was applied to the percent relative dishabituation scores, $H(1) = 1.0$, n.s., revealed that the proportion of newborns displaying increases in looking during the first test trial were similar for each negative state classification. This analysis suggests that negative state levels during the habituation phase did not influence looking during the test phase.

Next, the number of newborns demonstrating the exponential decrease, increase-decrease, or fluctuating patterns of habituation for Low State and High State categories was determined (Table 9). Chi-square analysis revealed that pattern of habituation classification was not biased by negative state levels, $X^2(2)= 1.6$. This analysis indicates that newborns expressing higher negative state levels during the habituation phase were no more likely to display exponential decrease or increase-decrease patterns of habituation than were the other newborns.

Finally, Pearson correlations were conducted between negative state variables (i.e., total negative state, last habituation trial, first test trial, first novelty trial, last habituation trial + first test trial, and last habituation trial + first novelty trial) and indices of habituation (i.e., total habituation looking time, last

Table 9

Number of newborns displaying exponential decrease, increase-decrease, and fluctuating patterns of habituation classified as Low State and High State.

Patterns of Habituation	State Classification	
	Low State	High State
Exponential Decrease	7	6
Increase-Decrease	5	2
Fluctuating	27	31

habituation trial looking time, magnitude of habituation), dishabituation (i.e., first test trial looking time, percent relative dishabituation), and recovery (i.e., first novelty trial looking times). No correlations approached the .05 level of significance (Table 10). The lack of significant correlations again indicate that looking times were not related to level of negative state expressed by the newborns.

Summary of negative state results. Overall, mean negative state displayed a linear increase between baseline and novelty. However, negative state was not correlated with indices of habituation, dishabituation, and recovery. As such, it is assumed that the obtained differences in test phase looking resulted from the manipulation of post-habituation delay and not from negative state differences between the delay conditions.

General Summary

Newborns displayed renewed interest to the first re-presentation of the Maltese Cross only following post-habituation delays of 90 s and 120 s. Stimulus movement and negative state did not influence the newborns' looking times following the delays. Moreover, differences in looking during the first test trial cannot be attributable to a general decline in looking by newborns in the 0 s, 30 s, and 60 s delay conditions, because newborns, on average, demonstrated significant increases in looking to the

Table 10

Correlation bewteen indices of negative state (s) and looking (s).

State Indices	Looking Indices (n = 78)					
	Last Hab	First Test	First Nov	Rel Hab	Rel Dishab	Rel Rec
Hab	-.03	.13	.07	-.15	.14	.10
Test	-.13	-.03	-.10	-.10	.07	-.05
Nov	.12	.12	.08	-.11	.05	.04
Dishab	.09	.07	.01	-.15	.13	.04
Rec	.06	.16	.09	-.16	.12	.11

Last Hab = Last habituation trial (s)
First Nov = First test trial (s)
First Nov = First novelty trial (s)
Rel Hab = Relative habibutation (%)
Rel Dishab = Relative dishabituation (%)
Rel Rec = relative recovery (%)
Hab = Last habituation trial (s)
Test = First test trial (s)
Nov = First novelty trial (s)
Dishab = Last habituation trial + first test trial (s)
Rec = last habituation trial + first novelty trial (s)

presentation of the modified Maltese Cross during the first novelty trial.

The vast majority of newborns exhibited fluctuating patterns of habituation. However, exponential decrease and increase-decrease patterns were also observed. Although newborns classified as fluctuating looked at the Maltese Crosses more and required more trials to reach criterion of habituation, patterns of habituation had no influence on test phase looking.

CHAPTER IV

Discussion

The results imply that newborns remembered the "habituated" Maltese Cross for 60 s. Newborns in the 0 s, 30 s, and 60 s delay conditions remained habituated (i.e., did not display an increase of looking) to the first representation of the Maltese Cross following the delay. On the other hand, newborns in the 90 s and 120 s delay conditions displayed a significant increase in looking time during the first test trial following the delay.

Finally, looking times increased when the modified Maltese Cross was presented in the novelty phase. The increase in looking to the novel stimulus indicated that test phase looking was not the result of a gradual decrease in overall looking across the entire testing procedure. Also, newborns presented with the Maltese Cross rotating for the first time (i.e., stationary to rotating) had a tendency to display higher initial looking times relative to newborns seeing the Maltese Cross undergoing a novel direction of rotation (i.e., clockwise to counterclockwise rotation).

These results indicate that newborns are capable of: (1) encoding visual information about stationary and rotating stimuli; (2) retaining this information for 120 seconds; and (3) retrieving this information to detect novelty. In other words, newborns process and retain information about stationary and rotating visual stimuli.

Processing of information at the level of the visual cortex has been demonstrated at birth (Laplante et al., in press; Slater et al., 1982, 1983). Moreover, memory retention is also thought to involve the cortex in infancy (Bhatt, Rovee-Collier, & Weiner, 1994; Hayne, & Rovee-Collier, 1995; Rovee-Collier, 1984). Yet, the specific information processing capacities of the visual cortex at birth are still highly debated (Bronson, 1974, 1982; Dannemiller & Banks, 1983, 1986; Johnson, 1990; Morton & Johnson, 1991). Thus, prior to advancing an information processing explanation involving the visual cortex, it must be demonstrated that the visual cortex was involved in processing the stationary and rotating Maltese Crosses.

Subcortical versus Cortical Processing

It has been proposed that cortical control of vision is not present in the human infant until approximately 2-to-3 months of age (Bronson, 1974, 1982; Johnson, 1990; Morton & Johnson, 1991). Prior to this age, perception of visual objects is assumed to be regulated by the subcortical retino-collicular pathway. This position is supported by evidence indicating that the superior colliculus is partitioned into its adult layers by 24 weeks gestation (Stampalija & Kostovic, 1981) and that myelination of the retino-collicular pathway begins prenatally (Yakovlev & Lecours, 1967). In comparison, projections from subcortical to cortical structures do not begin myelination until just

prior to birth, at which time rapid myelination occurs (Johnson, 1990; Schiller, 1985; Yakovlev & Lecours, 1967). Moreover, anatomical studies of the human newborn cortex (e.g., Conel, 1939) clearly demonstrate that differentiation of the primary visual cortex does not occur until several months postnatal. As such, afferent pathways from the lateral geniculate nucleus of the thalamus and those from the superior colliculus terminate at immature locations at the cortical levels (Conel, 1939). Thus, the subcortical pathways of the visual system are better developed at birth than are the cortical pathways.

However, studies of diagonal line (Slater et al, 1988; Orr et al., 1995) and direction of movement (Laplante 1992; Laplante et al., in press; Neville et al, 1995) discrimination provide behavioural support for cortical activity at birth, as feature detectors for these elements are found only at the level of the visual cortex. For example, while the superior colliculus may be involved in visually orienting newborns to moving objects, the ability to detect movement changes resides within direction-sensitive receptors located at the level of the visual cortex (Hamer & Norcia, 1994).

The novelty phase results of the present study (i.e., newborns detected changes to the direction of stimulus movement) validate the findings of Laplante et al. (in press) and provide further evidence for cortical functioning

at birth. While the visual cortex of a newborn has yet to reach its mature stage of development, the present data provides strong support for Maurer and Lewis's (1979) position that some processing at the level of the visual cortex is seen at birth.

The findings of the present study suggest that both the retino-collicular (i.e., detection of stimulus movement) and geniculo-cortical (i.e., discrimination of stimulus movements and pattern encoding) pathways are functionally present at birth. The similar habituation and delayed recognition findings for rotating and stationary stimuli, as well as the movement discrimination findings, imply cortical involvement. Thus, a cognitive explanation of the results can be advanced.

Delayed Recognition Memory for Stationary and Rotating Maltese Crosses

Habituation phase. The habituation phase findings imply that newborns encode information pertaining to moving and stationary stimuli at the same rate. Both criterion to habituation and magnitude of habituation measures failed to distinguish between newborns viewing the rotating or stationary Maltese Cross. While newborns displayed longer first looks toward the rotating Maltese Cross during baseline, these differences did not influence the process of habituation. A reason for why the hypothesized stimulus

movement effect was not obtained is presented later in the discussion.

Novelty phase. The result of the novelty phase clearly indicate that newborns compared and contrasted information pertaining to the modified Maltese Cross (i.e., a change in movement status) with the "habituated" Maltese Cross. The increase in looking demonstrates that a mismatch occurred between the stored neuronal model of the "habituated" Maltese Cross and that of the novel Maltese Cross. These results imply that newborns are capable of object discrimination based upon stimulus movement information.

The obtained novelty phase results also argue against a generalized behavioural fatigue explanation of habituation and retention on two counts. First, a significant increase in looking was obtained for the first novelty trial relative to the last habituation trial, regardless of delay condition. This result clearly indicates that newborns in the three conditions who, in general, remained habituated (i.e., 0 s, 30 s, and 60 s) during the first test trial did not do so because they were fatigued. If behavioural fatigue accounted for the depressed looking times obtained during the test phase, looking times should have remained at the same, if not lower, level during the novelty phase, especially since a linear increase in negative state was obtained. This did not occur.

Second, no correlations were obtained between the six negative state measures and measures of looking during each experimental phase. The lack of significant correlations (i.e., no correlation even approached significance) further supports the position that habituation and retention of visual information resulted from something other than generalized behavioural fatigue.

Theoretical explanation of habituation and recovery. Newborn habituation and recovery to novelty can be explained using the stimulus comparator theory proposed by Sokolov (1963). The basic premise of this theory is that incoming sensory information (i.e., from eyes, ears, skin) is compared with an existing neural model of previously encountered stimulation at the level of the cortex. If a match exists between the neural model and the incoming information, the organism's orienting reflex (i.e., hypothetical mechanism that directs the organism's attention to novel information) is inhibited, resulting in no observable behaviour. If, however, there exists a mismatch between the incoming information and the existing neural model then the orienting reflex occurs, resulting in an observable behaviour believed to indicate attention or interest about the information. Moreover, the magnitude of the orienting reflex is directly related to the size of the mismatch (Siddle, Kuiack, & Stenfert Kroese, 1983). The

bigger the discrepancy between the incoming information and the neural model, the greater the orienting reflex.

From an information perspective, habituation of visual attention towards a visual display is thought to reflect the reciprocal mental processes of memory trace construction and comparison (Bornstein, 1988, 1989b). Mental construction is believed to consist of the newborns' active encoding and storing of the visual stimulus. This process may be aided by Sokolov's orienting reflex, but is not restricted to a simple reflexive action. The end product of stimulus encoding and storing is the development of a mental representation (i.e., memory trace) of the visual array. The process of mental comparison consists of the newborns' continuous need to contrast incoming information about the visual stimulus with their developing mental representation of the stimulus. Thus, the reduction of visual attention, which defines habituation, reflects the development of the newborns' memories for the repeatedly presented stimulus. Therefore, habituation of visual attention is thought to indicate central processing functioning which is present at birth.

Bornstein (1989a) argues that recovery of visual attention to a novel object provide the clearest demonstration of central processing because attention will only recover if differences between the familiar and novel objects are detected. This ability to discriminate between

familiar and novel objects indicates that newborns are capable of remembering salient properties of the familiar object. Moreover, this ability indicates the use of the memory trace of the familiar object as a base from which to compare incoming information. If the incoming information matches what is already in memory, no further attention is required. On the other hand, if the incoming information does not match the existing memory trace, further attention is required and newborns display a recovery in their level of attention. Thus, differential attention towards the novel stimulus during post-habituation trials can be used as a valid measure of an infant's information processing.

In general, habituation of visual attention is believed to reflect the formation of a mental representation of the external visual array. Newborns reduce their amount of visual attention as their mental representations becomes more developed. Therefore, low levels of attention after several repeated presentations of the visual array is assumed to announce that memory traces of the object have been formed. As such, the reduction in attention is associated with the development of memory traces, which according to the information processing approach is essential to cognitive functioning (Bornstein, 1988). More importantly, a renewal of attention to a novel visual array indicates that newborns are capable of using their mental representations of familiar objects as a means of comparing

new information. When the novel incoming information does not match their existing mental representations, attention is heightened. Thus, habituation and recovery reflect the internal processes of memory trace formation and mental comparison. Both of these processes are important within a model of information processing.

In terms of the present study, the significant decline in newborn looking indicates that internal neural models of the rotating and stationary Maltese Crosses were developed. The increase in looking to the Maltese Crosses during the novelty phase also indicates that newborns compare incoming information with their previously neural models to detect novelty. The stimulus comparator, however, does not address the issue of duration of memory trace. The obtained findings during the test phase provide some insight into the duration of mental engrams (i.e., memory traces) at birth.

Test phase. The Delay Condition main-effect for dishabituation status indicate that newborns in the five delay conditions responded differently to the first re-presentation of the Maltese Cross during the test phase. The Dunnett's tests conducted on the dishabituation status scores clearly showed that memory traces for visual stimuli are readily retrievable at birth for up to 60 seconds. The Kruskal-Wallis analysis indicated that a greater proportion of newborns in the 90 s and 120 s delay conditions relative to newborns in the 0 s, 30 s, and 60 s delay conditions

demonstrated increases in looking during the first trial following the delay. However, when looking was averaged across the three test trials newborns in all trials failed to demonstrate any significant change in post-delay looking relative to looking levels exhibited during the habituation phase.

The test phase findings suggest that information contained within memory traces is readily accessible following delays of 60 seconds, but requires priming for delays greater than 90 seconds. This statement is based on the finding that while analyses conducted using the three test phase trials revealed no significant differences in looking time between the five delay condition, analyses conducted using the first test phase trial only revealed a significant main-effect of delay condition. Newborns in the 90 s and 120 s delay conditions displayed significant relative dishabituation, but only when their looking on the first test trial was assessed. When total test phase looking was assessed, newborns in the 90 s and 120 s delay conditions did not differ from those in the three remaining delay conditions. In actuality, newborns in all delay conditions, except for the 0 s delay condition, had lower looking times when total test phase looking was assessed. Newborns in the 0 s delay condition displayed a slight increase in looking (i.e., 0.2 s) when all test phase trials were assessed. The difference between the obtained results

of the analyses of variances conducted using the first test trials and all three test trials is of great importance become it suggests that memory traces for stationary and moving visual stimuli are held in memory for at least 120 s.

Memory reactivation. To account for the obtained differences in statistical outcomes, it is necessary to borrow the concept of memory reactivation from the work of Rovee-Collier and her colleagues (Rovee-Collier, 1984, 1995; Rovee-Collier, Enright, Lucas, Fagen, & Gekoski, 1981; Rovee-Collier, & Hayne, 1987; Rovee-Collier, Sullivan, Enright, Lucas, & Fagen, 1980; Sullivan, 1982; Vander Linde, Morrongiello, & Rovee-Collier, 1985). Rovee-Collier (1995) believes (and her research supports her claims) that potentially forgotten memories, which may still reside in long-term memory (c.f., Tulving, 1972), can be made accessible if cues are provided prior to placing the infant in the test situation. Using a conjugate footkicking paradigm, Rovee-Collier has shown that 2-month-old infants can remember a previously learned behaviour (i.e., kicking one's foot will cause a mobile to move) if a single reminder (i.e., 3 min of exposure to the situation) is provided up to 3 weeks after training has been completed. At the same age, if the reminder is provided 4 weeks after termination of training, infants treat the test situation as novel (i.e., do not kick beyond previous baseline amounts). Moreover, infants placed in the test situation 3 weeks later, but who

have not had a brief re-training session, also treat the testing situation as novel. Thus, what appears to have been a forgotten behaviour can be reinstated by briefly re-exposing the infant to the stimulus contexts.

While it is not my intention to equate looking time and conjugate footkicking, I believe that the underlying principle behind memory reactivation can be applied to the obtained findings. That is, presentation of previously experienced events can facilitate memory retrieval in newborns. The obtained results appear to support this position.

The nonsignificant difference in looking time for all five delay conditions when the average looking of the three test phase trials was analyzed suggests that newborns retained information about the Maltese Cross for the longest examined delay period (i.e., 120 s). Yet, the differences in looking when only the first test trial was analyzed suggest that newborns in the 90 s and 120 s delay conditions required a reminder. As such, it is believed that the first test trial activated that newborns' long-term memory system. Once activated by the first test trial presentation, newborns were then able to match the "habituated" Maltese Cross with their stored memory trace. Thus, the differential results of the two analyses suggest that after the memory trace was made readily available by the reminder (i.e., the first test trial), the average test phase looking

became equivalent across the five delay conditions. While the design of the present study does not allow for a direct analysis of this assumption, it remains that memory reactivation provides the best first attempt at explaining looking during the test phase of the present study.

The results suggest that newborns developed a memory trace for the Maltese Cross over successive presentations. The memory trace was then stored within the newborns' cognitive system (i.e., long-term memory). Once encoded, it appears that information pertaining to the Maltese Cross (i.e., pattern, shape, and movement) resides "permanently" within the memory storage system. What appears to quickly decline is the ability to readily retrieve these memory traces. The present results suggest that at birth the ability to retrieve memory traces without priming (i.e., upon initial re-presentation of the "habituated" stimulus) begins to deteriorate 60 seconds following the removal of the to-be-remembered stimulus. Retrieval following delays longer than 60 seconds appear to require some form of cuing. The cuing in the present study was provided by the presentation of the Maltese Cross during the first test trial.

Time windows. While the present study did not follow the memory reactivation protocol outlined by Rovee-Collier and her colleagues (c.f., Rovee-Collier, 1995), memory reactivation remains the best explanation for the obtained

findings. Memory reactivation becomes even more likely when coupled with Rovee-Collier's (1995) premise of time windows of memory functioning. According to Rovee-Collier (1995) a time window of memory functioning operates similar to the concept of a critical period. Time windows of memory functioning are periods during which incoming information can be integrated with existing memory traces. A time window opens when novel information is experienced and closes when the information is forgotten. Once a time window for a particular experience is closed, additional incoming information (i.e., even information pertaining to the experience which resulted in the opening of the time window) is treated as novel. However, time windows can be extended by providing additional experience toward the end of the period. Memory reactivation procedures expand the interval during which time windows remain open. This is important since memories can only be retrieved while the time window for the experienced event remains open.

Rovee-Collier (1995) reports that there exists upper limits for which a reminder can reactivate an apparently forgotten memory. More importantly for the present study, the extent to which times windows can be expanded appears to be age-related. That is, the younger the infant, the earlier the reminders must be presented. For example, Greco, Rovee-Collier, Haynes, Griesler, & Earley (1986) report that at 2 months of age, an apparently forgotten

memory can be retrieved if a reminder is presented 3, but not 4, weeks following termination of training. By 4 months, reactivation can occur 4, but not 5, weeks post-training (Rovee-Collier et al., 1980). Work with younger infants has not been conducted. This work suggests a developmental change in the ability to reactivate apparently forgotten memories.

Newborns appear to be able to readily retrieve memories for visual stimuli for up to 60 seconds. After 60 seconds, newborns require a reminder (i.e., re-presentation of the Maltese Cross) to retrieve the stored memory trace. As such, the time window for visual events experienced within a habituation-dishabituation-recovery procedures appears to be 120 seconds, if a reminder is presented. The upper limits of memory reactivation for apparently forgotten visual stimuli still remain unknown. However, the results of the present study have provided important information pertaining to newborn cognitive functioning: memory trace duration is longer than previously reported. Further research is required to explore the upper limits of memory traces at birth.

Comparison with auditory findings. The findings of the present study are similar to those obtained by Zelazo et al. (1987). In both studies, newborns readily retrieve encoded information about familiar stimuli (i.e., Maltese Cross and spoken words) after delays of approximately 60 s. The

similarity of the results clearly suggest that delayed recognition memory is modality independent. The visual and auditory findings suggest that these measures tap central information processing abilities (Morrongiello, 1988).

Furthermore, the concept of memory reactivation used to explain the discrepancy between first and all test trial looking can also be used to explain the results of Swain et al. (1993). As with the present study, Swain et al.'s (1993) study strongly suggests that memory traces are permanent, but require retrieval prompts following delays longer than 60 s. Repetition of a word on two consecutive days increased memory trace retrieval from 55 s to 145 s. Swain et al.'s (1993) study also suggests that the time window for reactivating apparently forgotten information may be extended to 24 hours. However, further research is required to substantiate this claim.

Conclusions. In conclusion, delayed recognition memory for visual and auditory events appear to correspond to each other. At birth, stored memory traces can be retrieved following delays of 60 s without prompts. Memory reactivation procedures greatly extend memory trace retrieval. The similarity of the visual and auditory findings supports the belief that modality independent, central processing abilities are present at birth. The obtained findings also provide empirical support that visual processing is similar to that of other measures (i.e., sound

processing) also believed to indicate information processing at the cortical level (Clifton, Morrongiello, Kulig, & Dowd, 1988; Lewkowicz, 1992; Lewkowicz & Turkewitz, 1981; Zelazo, 1988a).

Rovee-Collier's (1995) concepts of memory reactivation and time windows of memory functioning provide a potential, and highly plausible, explanation for the observed looking behaviour of newborns in the present study. The obtained data appear to support the notion that apparently forgotten memories can be reactivated using simple reminders. Moreover, the similarity in delayed recognition memory abilities for visual and auditory stimuli imply central information processing.

Individual Variation During the Test Phase

Overall, newborns appeared to remember the Maltese Cross following delays up to 60 s, and did so after 60 s with prompting. Yet, not all newborns in the 0 s, 30 s, and 60 s delay conditions remained habituated to the re-presentation of the Maltese Cross during the test phase. Likewise, not all newborns in the 90 s and 120 s delay conditions displayed significant increases in looking during the test phase.

These findings exemplify the variability seen in newborn visual processing (c.f., Colombo, 1993). It appears that some newborns are less able to retain information, while others apparently were able to retain this information

for at least 120 s (i.e., the longest delay period assessed in the present study). However, it is encouraging to note that only two of 16 newborns in the 0 s delay condition appeared to forget about the Maltese Cross during the first test trial. This is encouraging because the number of dishabituators in the control condition does not exceed what is frequently observed; some control babies appear to act like experimental babies. Likewise, two-thirds of the newborns in the 120 s delay condition dishabituated. Moreover, the looking behaviour of newborns in the 0 s and 120 s delay conditions best substantiate the hypothesis. Newborns form memories for visual event, but these memories have short-term accessibility. The looking in the three middle delay conditions demonstrate that a wide variability of cognitive functioning can be seen at birth.

Individual Patterns of Habituation

The obtained data demonstrate that newborn habituation cannot be described as a smooth and continuous linear decrease in visual fixations. Approximately 75% of newborns in the present study exhibited patterns of habituation that were anything but linear in nature. Habituation at birth can be best described as involving large trial-to-trial fluctuations of stimulus-directed looking.

Evidence against a selective receptor adaptation model of newborn delayed recognition. These findings provide evidence against the selective receptor adaptation model of

habituation, as looking is negatively correlated to cortical fatigue. If receptor fatigue regulated habituation, exponential decreasing patterns should have been most prominent. Only 16.7 and 8.9 percent of newborns displayed exponential decreasing and increase-decreasing patterns of habituation, respectively. Thus, approximately only 25% of newborns displayed patterns of habituation that could be explained by a selective adaptation model of newborn habituation. If receptor fatigue was responsible for habituation, the majority of newborns (allowing for some variation) should have displayed a gradual decline in looking times with increased exposure to the Maltese Crosses since cortical fatigue is correlated to the extent one is exposed to incoming information. In fact, some newborns displayed actual increases of their looking times during the final three habituation phase trials. Increases in looking times late in the habituation phase strongly suggests that habituation results from something other than receptor fatigue.

The prominence of the fluctuating pattern of habituation, coupled with the obtained test phase results suggest that cognitive factors regulated habituation. The cognitive factor most likely involved in differentiating newborns between efficient and unorganized processors is the ability to sustain attention on task relevant information (Lécuyer, 1988). Thus, I wholeheartedly agree with Zelazo,

Weiss, and Tarquinio (1991) when they write "these data[6] are sufficiently decisive and consistent to put the SRA[7] hypothesis to rest. It does not appear to be a viable model to account for neonatal habituation and recovery of head-turning toward auditory stimuli" (p.134, footnotes added).

Processing efficiency. The present findings provide support for Bornstein and Benasich's (1986) contention that habituation becomes more precise (i.e., becomes more linear in nature) with increased age and experience. While 60% of infants in Bornstein and Benasich's study exhibited exponential decrease patterns, less than 20% of newborns did so. The shift between unorganized to organized habituation may reflect the infants' growing ability to sustain their attention on the stimulus. The ability to sustain attention of task relevant information increases infants' capacity to process information, thereby increasing speed of processing (Lécuyer, 1988; Zelazo et al., 1995).

In terms of increased processing capacity, the present findings demonstrate that newborns exhibiting an exponential decrease required fewer trials to obtain criterion of habituation and did so with less overall looking. Newborns exhibiting this pattern of habituation developed memory traces for the Maltese Crosses faster than unorganized

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[6]Newborns remain habituated to, and actively turn away from, the re-introduction of a familiar sound for periods up to 55 s.

[7]Selective receptor adaptation.

newborns. Thus, patterns of habituation may represent another manner in which to determine underlying individual differences in the ability to encode visual information. Thus, individual differences in duration of looking (Colombo, 1993; Colombo et al., 1991; Freeseman et al., 1993) and patterns of habituation may be observed.

Interestingly, efficiency in stimulus encoding is not related to the ability to later retrieve memory traces. Newborns displaying the three patterns of habituation displayed comparable test phase looking. This suggests that retrieval of stored memory traces is not influenced by the manner in which it was developed.

Effect of Stimulus Movement on Habituation, Retention, and Response to Novelty

Hypothesis II stated that the introduction of stimulus movement (i.e., rotation) would have an influence on delayed recognition memory in newborns. Furthermore, it was hypothesized that stimulus movement would increase the attention-getting properties (i.e., decrease latency to first looks) of the Maltese Cross thereby increasing initial looking times, facilitating habituation, and altering the duration for which newborns could retain visual information. Clearly, the obtained data do not support the latter two points. When presented alone, the rotating Maltese Cross did not result in more pronounced habituation nor did it alter (i.e., increase or decrease) the duration for which

visual information could be retained. However, the rotating Maltese Cross was initially looked at longer. Likewise, newborns responded with longer looks (i.e., in term of percent relative recovery) to the Maltese Cross undergoing the most striking movement modification (i.e., from stationary to rotating) in the novelty phase. Each of these points will be expanded upon in the following sections.

Effect of stimulus movement during the habituation phase. The rotating Maltese Cross did not attract the newborns' attention faster than the identical stationary one. This finding is contrary to that reported by Cohen (Cohen, 1973; Cohen & Gelber, 1975) with older infants. The failure to demonstrate the reported increased attention-getting properties of moving stimuli may be linked to the central presentation of the two stimuli in the present study.

For example, both the rotating and stationary Maltese Crosses were presented in the centre of the newborns' visual fields. By presenting the stimuli in the centre of the visual fields, and by having the holder orient the newborns' heads toward the centre of the visual chamber, any potential influence of stimulus movement (i.e., increases speed of stimulus capture) may have been reduced. By focusing on differences in attention-maintenance following delays (which was the primary aim of the study), the procedure may have

potentially reduced the attention-getting capabilities of moving stimuli.

In order to assess the attention-getting properties of stimulus movement at birth, off-centre presentations of moving and identical stationary stimuli may be required. Using this form of stimulus presentation, it may be possible to discern whether stimulus movement influences latency to first fixations. However, this remains to be empirically tested.

Newborns did, however, fixate the rotating Maltese Cross longer on their first look. This finding suggests that once newborns are able to lock onto visual stimuli, they initially attend to a moving one longer. This finding provides partial, and admittedly weak, support for the claim that newborns prefer moving stimuli (Slater et al., 1985). Again, it is possible that the fixed 30 second trial period may have accounted for the failure to detect overall looking time differences as a function of stimulus movement.

It is unfortunate that the program written to collect the looking time information did not indicate the relative position of each discrete fixation within the 30 s trial. If the data were stored in this manner, a reanalysis using one second of nonstimulus-directed looking as an indication of trial termination could have been applied to the present data to approximate a newborn/infant-controlled procedure. As it stands, it can only be speculated that within a

newborn/infant-controlled procedure, the obtained differences in looking times directed at two Maltese Crosses may have substantiated the hypothesis that stimulus movement works to increase baseline attention, thereby, potentially increasing the rate at which newborns reach criterion of habituation. Again, this explanation needs to be empirically tested.

Newborns' response to movement modifications. Newborns displayed relative recovery to movement modifications, apparently preferring the Maltese Cross that changed from stationary to rotating (i.e., it was looked at faster) over that which rotated in a novel direction. This result is interesting for two reasons. First, it provides validation that newborns can process movement changes. Second, it demonstrates that certain movement modifications elicit greater attention than others. Each point will be addressed.

Until recently, it was believed that infants below the age of 2 months could not detect direction-specific motion information (Bertenthal & Bradbury, 1992; Freedland & Dannemiller, 1987; Hamer & Norcia, 1994; Johnson, 1990; Johnson, Dziurawiec, Ellis, & Morton, 1991; Morton & Johnson, 1991; Wattam-Bell, 1991). However, Laplante et al. (in press) reported that detection of absolute motion changes are possible at birth; a finding not supported by Slater et al. (1985). The observed increases in looking

when rotation was reversed provides support for Laplante et al.'s (in press) findings. The results of the present study confirm that newborns are sensitive to direction-specific motion information. Moreover, the ability to detect movement changes is not impeded by additional post-habituation exposure to the stimulus. Newborns in the five delay conditions displayed comparable relative recovery scores.

The finding that different types of stimulus movement modifications are attended to differently was surprising. One possible explanation for this finding is that newborns are predisposed to attend to certain movement modifications over others. To this end, the previously stationary Maltese Cross (which is now rotating) may have been perceived as a greater threat (c.f., Ball & Tronick, 1970; Dunkeld, & Bower, 1980);, and thus increased the vigilance of the newborns. It is interesting to note that differences in both overall looking times and latency to first look were obtained for the first novelty trial. Newborns oriented to the previously stationary Maltese Cross twice as fast as toward the previously rotating Maltese Cross. While speculative, increased vigilance to potential threats does offer a possible explanation for the obtained novelty phase differences in looking behaviour.

To empirically test this hypothesis post-habituation presentations of stimuli comprised of modified movements

would need to contain stimuli which either moved towards of or away from the newborns. If newborns are reacting on the basis of some predisposition to orient toward threatening stimuli, they should orient toward and attend to stimuli approaching them more than stimuli remaining in the same plane or retreating away from them.

Regardless of whether the previously stationary Maltese Cross was perceived as more threatening, or whether it represented a novel object of greater magnitude, the results are consistent with those obtained by Laplante (1992). Stimulus movement appears to have a greater influence on novelty processing than on the process of habituation at birth. Laplante (1992) demonstrated that newborns detected line orientation changes of moving stimuli faster (but not to any greater extent) than stationary stimuli. Thus movement or movement changes appear to prime the newborn to detect changes to previously observed objects. To this extent, stimulus movement may help the newborn to extract novel information for objects they experience.

General Conclusions

The findings of the present study provide convincing evidence that delayed recognition memory involves information processing. The delay periods for which looking times remained habituated far exceed refractory periods of cortical neurons and cannot be explained by behavioural fatigue. Moreover, the obtained nonsignificant differences

in looking between the five delay conditions when analyses were applied to the mean looking across the three test trials suggest that memory traces are apparently permanently stored in long-term memory. What appears to decline, as evidenced by differences in looking during the first test trial, is the newborns' ability to readily retrieve stored memory traces. Rovee-Collier's (1995) memory reactivation construct provides a useful explanation to account for the differences between first and all test phase looking. The first re-presentation of the Maltese Cross after delays of more than 90 s primed the newborns' long-term memories. Priming of long-term memory makes successful matching of incoming information with previously stored memory trace possible on subsequent presentations. Finally, the fluctuating pattern of habituation observed in the majority of newborns suggests that the means by which memory traces are developed do not influence memory trace duration. Efficient and unorganized processors of visual information demonstrated comparable retrieval abilities. The fact that most newborns exhibited fluctuating patterns of habituation also supports the notion that newborn habituation is cognitive and not limited solely to receptor fatigue.

CHAPTER V

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APPENDIX

A

PARENTAL CONSENT FORM

Department of Psychology

University of Windsor

DELAYED RECALL MEMORY IN NEWBORN INFANTS.

Project Director: R. Robert Orr, Ph.D.
Doctoral Student: David P. Laplante, M.A.

Before your child can be included in this study, being conducted by David P. Laplante under the supervision of Dr. R. Robert Orr, the entire procedure must be explained to you. Any questions that you may have concerning the study must be answered to your satisfaction and if you agree to your child's participation you must sign the attached form.

The purpose of this study is to determine whether 2- or 3-day-old infants are capable of forming memories of either a stationary or rotating black-and-white Maltese Cross. In order to answer this question your child will be presented with the striped pattern and his/her visual attention (as measured by the amount of time your child looks at the picture) will be evaluated for a varying number of trials. The length of the participation depends upon how long your child looks at each presentation of the pattern. Once your child's attention to the Maltese Cross has declined a short delay will be imposed. After the delay your child will be presented with the Maltese Cross for three additional trials. Following this, three additional trials will be presented during which the Maltese Cross will be modified. The entire procedure is estimated to last 30-45 minutes.

During all phases of the procedure only your child's visual attention level, amount of drowsiness (as measured by incidence of eyes closed), and crying will be recorded. At no time will drugs or injection be given nor will your child come into direct contact with the equipment used to measure his/her visual attention. The results of the procedure will be explained to you after you child has completed this study.

During the study your child will be seated on the lap of one of the experimenters so that he/she can see the Maltese Cross. The pattern will be repeatedly presented to your child (30 seconds per trial) until he/she becomes disinterested in it. When your child looses interest in the pattern a short delay will be imposed. Following the delay the same pattern will be represented. The actual length of the delay which will be imposed is randomly assigned for each child.

Your child's visual attention will be measured by looking at the pattern's reflection in his/her eyes. The viewing chamber is designed in such a manner that the lighting is never directed at your child's eyes. The amount of attention your child displays, as well as all instances of eyes closed and crying will be recorded and stored into a computer program. The information will be stored in such a manner that the identity of your child cannot be determined. Likewise, the procedure may be videotaped for later reanalysis. Videotapes will be stored in such a manner that the identity of your child will be known only to the principle investigator. At no time will the videotape be distributed without your prior consent.

This study is not an evaluation of your child and is not a test of how well your child is doing. We are conducting this study in an attempt to better understand how young babies react to changes in their surroundings. It is hoped that one day this type of study will lead to a test of newborn capabilities.

This research has been reviewed and cleared by the Ethics Committees of the Salvation Army Grace Hospital and the Department of Psychology (University of Windsor). If you have any complaints regarding the present study and/or the conduct of the researchers involved with the study, please feel free to contact Dr. Ron Frisch at the University of Windsor Psychological Services Centre (253-4232, ext. 7012). Dr. Frisch is the Chair of the Department of Psychology's Ethics Committee.

STATEMENT OF INFORMED CONSENT

NAME OF CHILD:_____ DATE:_____

The nature of this research procedure has been explained to my satisfaction. All of the procedures, including the equipment used to record the results were explained to me. I understand that I am able to ask questions concerning the procedures at any time (before, during, and after). I know that the interpretations of all test results will be shared with me.

My child's identity and study results will be kept confidential. I give my permission to use my child's results for any publications that may result from this study.

I have read and understand the description of this study and I am willing to allow my child to participate in this study. I have been given an opportunity to write in below any limitations or restrictions with this statement.

_____

_____

_____

_____

I understand that I may choose not to have my child participate in this study. If for any reason I wish to discontinue my child's initial participation, I am free to do so. In no way will this affect my child's future care or treatment at the Salvation Army Grace Hospital.

Do you wish to obtain a copy of any scientific papers that may arise from this research. ____ Yes ____ No

If yes, please provide your mailing address.

_____

_____

_____

I have received a copy of this consent form.

If necessary, you can contact David P. Laplante at the University of Windsor. tel: 253-4232 (2217)

Signed:_____
Parent

Signed:_____
Investigator

Signed:_____
Witness

APPENDIX

B

Equations used in Results Section

(1) Equation for Mean Percent Relative Dishabituation

$$\text{Mean Percent Relative Dishabituation} = \frac{\text{Mean First Test}}{\text{Mean Last Habituation} + \text{Mean First Test}} \times 100$$

(2) Equation for Mean Magnitude of Habituation

$$\text{Mean Magnitude of Habituation} = \frac{\text{Mean Habituation Trials}}{\text{Mean Baseline Trials}} \times 100$$