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THE IMPACT OF PRETERM BIRTH ON VISUAL ORIENTATION AT TERM AND EYE-HAND PERFORMANCE AT 12 MONTHS

BY

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research for acceptance, a thesis entitled **"IMPACT OF PRETERM BIRTH ON VISUAL ORIENTATION AT TERM AND EYE-HAND PERFORMANCE AT 12 MONTHS"** submitted by **Marisa Cotta Mancini** in partial fulfillment of the requirements for the degree of **Master of Science.**

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ABSTRACT

Seventy-three preterm infants were allocated to one of two groups according to their gestational age at birth (<32 weeks; 32-36 weeks). Because of the strong association between neurological outcome and developmental performance, forty-five neurologically normal preterm infants were identified at eighteen months of age and examined separately from the rest of the infants. The visual orientation of all infants was measured at forty weeks post-conception and their eye-hand performance was assessed at twelve months corrected age.

At term, the two gestational age groups of neurologically normal preterm infants did not differ significantly in terms of visual orientation responses. This study also failed to show a significant relationship between gestational age at birth and later eye-hand performance, in normal preterm infants. Furthermore, the visual orientation responses demonstrated by the normal preterm infants, at term, was found to be negatively associated with their eye-hand performance at twelve months corrected age. The extrauterine environment experienced by normal preterm infants neither enhanced nor retarded their visual orientation abilities at term, or their eye-hand performance at twelve months of age.

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INTRODUCTION

Prior to 1940, infants born prematurely received virtually no medical treatment; consequently, seventy percent of preterm infants died shortly after birth (Minde, 1984). With the advent of Neonatal Intensive Care Units (NICU), the life expectancy of very young preterm infants has increased significantly; the neonatal mortality rate in the United States has declined from 23 to 10 deaths per one thousand births. Currently, infants born as young as twenty-four weeks gestation and weighing less than 8 hundred grams are surviving (Allen & Capute, 1986; Kitchen et al., 1987).

Young gestational age at birth is often associated with poor neurological outcome (Pettett, 1986). Infants who are born too soon are more likely to have peri and postnatal medical complications than infants born at older gestational ages. These medical complications associated with young gestational age at birth threaten the optimal neurological development and may have a direct impact on later outcome (Pelletier & Palmeri, 1985; Ramm, 1988).

Preterm infants are known to be at risk for a number of minor developmental disorders including perceptual problems, delayed fine-motor performance, learning disabilities, and major disabilities such as cerebral palsy (Campbell & Wilhelm, 1985; Mulligan et al., 1980). They are also known to be at increased risk for vision-threatening conditions (Fledelius, 1976). One percent of preterm infants have some form of visual disablement. The most common ophthalmological problem among preterm infants is retinopathy of prematurity, however, the incidence of this problem has declined substantially with the control of oxygen therapy. Other visual impairments that can be found in preterm infants are reduced visual acuity, myopia, and strabismus (van-Holf van Duin & Mohn, 1984).

The visual system of preterm infants has been widely studied since its assessment is often used as a predictor of neurobehavioral development. Although the visual system is the last of the sensory systems to attain full maturity, many of its functions are used to assess neonates' behavioral responses at birth. Several investigators agree that the capacity of a neonate to fix, follow and alert to a visual stimulus provides information about the integrity of the visual pathway and may predict later intellectual performance (Brazelton et al., 1966; Dubowitz et al., 1980; Hack et al., 1981; Miranda et al., 1977; Placzek et al., 1985).

The role the extrauterine environment plays in the development of the preterm infant's sensory systems in general, and in the late maturing systems such as the visual system in particular, is still controversial. When the objective is to investigate potential factors that may alter developmental outcome it is important to first study the development of an optimal group of preterm infants. This study examined the impact of preterm birth on visual orientation at 40 weeks post-conception and on eye-hand performance at 12 months corrected age. In an attempt to separate the impact preterm birth may have on these factors from the influence associated with poor neurological outcome, infants neurological status were determined at 18 months. The group of preterm infants with normal neurological outcome at 18 months corrected age was then examined separately from the infants classified as neurologically suspicious and abnormal. Once neurological disorders have been controlled it allows meaningful examination of the impact of extrauterine experience on normal preterm infants' developmental outcome.

Relevance of the Study

While the advent of neonatal intensive care units has increased the life expectancy of very young preterm infants, there is still controversy as to what impact the artificial extrauterine environment has on the development of the central nervous system. Some investigators contend that the extrauterine environment has a positive effect and consequently, several aspects of preterm infants' development such as visual abilities are enhanced by this experience (Baraldi et al., 1981; Kopp et al., 1975; Palmer et al., 1982). Other investigators argue that the immaturity of many structures is negatively influenced by preterm birth, resulting in poor performance by this group of infants (Ferrari et al., 1983; Morante et al., 1982). In an attempt to add clarification to this conflict the present prospective study investigated the impact of preterm birth and the subsequent extrauterine experience on infants' ability to interact with the environment by means of early visual orientation and later eye-hand performance.

The integrity of both the sensory and the motor systems is extremely important for the child's interaction with the environment and the development of mature and specific abilities. Eye-hand coordination is one essential ability for the child's exploration of objects (Hofsten, 1982). Examining the impact of preterm birth on the acquisition of this visually directed fine-motor ability will provide important information as to the developmental outcome of fine-motor skills in preterm infants.

The study of early indicators of developmental outcome has become a major concern for pediatric therapists since these indicators give us information necessary to define which infants should be provided with therapy services. The present study intends to determine whether the visual orientation of preterm infants at 40 weeks post conceptional age and the gestational age at birth are indicators of eye-hand performance at 12 months corrected age. The findings from this study may provide useful information for early intervention programs directed towards improving the fine-motor developmental outcomes of infants born prematurely. Preterm infants are known to exhibit developmental delays in visual-motor skills (Holmes et al., 1988). If either gestational age at birth or visual orientation at 40 weeks post-conception are related to eye-hand performance at 12 months corrected age, they could be used for the early identification of children who are at risk for fine-motor disorders. Once such children were identified, early intervention programs could address the issue of enhancing development in this area.

Objectives

A) General Objective

The overall objective of this study is to evaluate the impact of preterm birth and the subsequent extrauterine environment experience on visual orientation at 40 weeks post-conceptional age and eye-hand performance at 12 months corrected age.

B) Specific Objectives

1. Evaluate the effect of gestational age at birth on visual orientation at 40 weeks post-conception by comparing the visual orientation of preterm infants born at different gestational ages.

2. Evaluate the relationship of the preterm infants' visual orientation at 40 weeks post conceptional age with their eye-hand performance at 12 months corrected age.

3. Examine the impact of gestational age at birth, visual orientation at 40 weeks post conception and neurological status at eighteen months corrected age as indicators of eye-hand performance at 12 months corrected age.

Research Null Hypotheses

1. Preterm infants less than 32 weeks gestation at birth do not differ significantly from preterm infants 32-36 weeks gestation at birth in their visual orientation at 40 weeks post-conception.

2. Visual orientation of preterm infants at 40 weeks post conception is not significantly related to eye-hand performance at 12 months corrected age.

3. Gestational age at birth, visual orientation at 40 weeks post-conception, and neurological status at 18 months corrected age are not significantly correlated with eye-hand performance at 12 months corrected age.

CHAPTER II

LITERATURE REVIEW

This review of the literature outlines two subject areas: the development of preterm infants and the development and assessment of infants' visual system and its interaction with motor performance.

Development of Preterm Infants

Preterm infants, by definition, are infants who are born before the completed thirty-seventh week of gestation and live in the extrauterine environment during the fetal period (Gesell et al., 1949; Prechtl & Nolte, 1984). Seven to 10% of all live births in the United States are preterm (Gorski, 1984). Preterm infants are viewed as a unique group of infants with specific characteristics and patterns of development (Aylward, 1981; Paludetto et al.,1984; Prechtl et al., 1979). Indeed, Prechtl & Nolte (1984) define preterm birth as a pathological event.

Preterm infants are challenged to live in an artificial environment during a period that is normally spent in utero. Many investigators have questioned whether this unique environment affects the behavioral and neurophysiological development of the preterm infant. Parmelee (1975) argues that preterm infants have an uneven development of behavior, and the extrauterine experience neither enhances nor retards their development due to the immaturity of their central nervous system. In 1980, Touwen described two opposing theories to explain the development of the central nervous system (CNS) of the preterm infant. The first suggests that the development of the CNS is a genetically preprogrammed process. An uncomplicated preterm birth would not affect the natural course of maturation. This first argument was supported by the earlier studies of Gesell (1933) and Saint-Anne Dargassies (1966) who contend that neurological development is biologically driven. The second theory presented by Touwen (1980) promotes the idea that the brain matures during the last months of fetal life and is environment-dependent. Contrary to Parmelee's (1975) position, Touwen's second theory (1980) suggests that the development of preterm infants may be either enhanced or retarded as a result of the extrauterine experience.

Previously, full-term neonates were thought to be helpless at birth and the environment would be a determinant factor in their development. Current research has shown that infants are born with the ability to actively interact with the environment (Rossetti, 1986). Controversy still exists concerning the classical issue of "nature" or maturational control versus "nurture" or experiential influence in human development. The study of preterm infants facilitates a better understanding of the factors that influence development. According to the "nature" argument the neuromotor development is an innate preprogrammed process and the development of preterm infants following an uncomplicated birth would not be affected by the extrauterine experience. This is much like Parmelee views the preterm birth experience. The "nurture" argument suggests that neuromotor development is affected by the environment and the extrauterine experience caused by preterm birth could either enhance or retard development. This argument runs parallel to Touwen's second theory, discussed above.

Saint-Anne Dargassies (1966) and Gesell (1933) advocate the "nature" viewpoint. Saint-Anne Dargassies (1966) describes the maturational process of preterm infants born from twenty-eight to forty weeks gestation. She reports that ontogenesis evolves according to the inherent biological structures and functions and that the environment does not enrich this process. Touwen (1980) promotes the "nurture" viewpoint and believes that there is evidence of environmental influence on the neurological development of preterm infants.

In agreement with Touwen (1980) many investigators have reported that the development of preterm infants is affected by their environmental experience. As mentioned previously, while a group of investigators contend that the extrauterine experience has a positive effect on specific aspects of preterm infants' development (Baraldi et al., 1981; Kopp et al., 1975; Palmer et al., 1982), another group argues that the environment has a negative impact on the immature structures of preterm infants (Ferrari et al., 1983; Morante et al., 1982). In agreement with the argument given by this last group of investigators Als (1986) presented a model for the dynamic organization of infant behavior in response to the stress imposed by the extrauterine environment. It was theorized that although stress is necessary for development, preterm infants are exposed to an excessive amount of stimuli (stress), which are imposed on their immature central nervous functioning and may result in poor quality of responses. According to this model there is a balanced interaction between the individual's behaviorally observed systems (i.e. autonomic, motor, state organizational, attention and interacting, and self-regulatory balancing systems) that allows the neonate to interact continuously with the environment. Because of the immaturity of preterm infants' nervous system, excessive stress from the NICU environment may jeopardize their behavioral balance and impact negatively on their neurological organization.

As a means of studying the effects of the extrauterine environment on the development of the newborn, several investigators have compared the neurobehavioral functions of low-risk preterm with full-term infants when both groups are forty weeks post-conception. The following studies are some examples of this approach. Ferrari et al. (1983) suggest that low gestational age at birth (less or equal to 33 weeks gestation) is associated with heterogeneous and poor behavioral organization among preterm infants when compared to full-term newborns. Forslund & Bjerre (1983) found the two groups to differ considerably in neurological development, e.g., in muscle tone and active motility. Gorga et al. (1985) report consistent differences between preterm and full-term infants in motor development and quality of movement with the greatest distinctions observed in the first six months of age. Between group differences were also found for activity states with the preterm group exhibiting lower scores (Michaelis et al., 1973). Some explanations for the differences found between low-risk preterm and full-term infants include intervening factors such as body weight, time of the examination of the full-term infants, state of alertness at the time of the examination (Prechtl & Nolte, 1984).

Besides differing from full-terms the preterm population has itself been considered a heterogeneous group of infants (Ferrari et al., 1983; Forslund & Bjerre, 1983). As a result, current studies have been investigating the impact of the extrauterine environment on infants' development by means of comparing preterm infants born at younger gestational ages with those born at older gestational ages. Piper at al. (1989) found that normal preterm infants born at two gestational age groups (less 32 weeks gestation; 32-36 weeks gestation) differed significantly in terms of primitive reflexes at four months corrected age. Also, Piper at al. (in press) reported that these two gestational age groups of preterm infants differed in their fine-motor development at eight and 12 months corrected age. These findings suggest that some aspects of the preterm infants' development are adversely affected by prolonged extrauterine experience.

With recent advances in ultrasound, it is now possible to study the influence of environmental differences on early development by comparing the fetus and the preterm infant at the same conceptional age. Cioni et al. (1986) described the incidence of motor patterns in the fetus and compared them with those of the preterm infant, at the same conceptional age. The results indicate that many items in the motor repertoire of preterm infants are similar to those described in the fetus. While many investigators agree that preterm infants differ from full-terms, there is still disagreement as to how preterm birth and prolonged extrauterine existence impact on specific developmental functions (Ferrari et al., 1983; Forslund & Bjerre, 1983; Gorga et al., 1985; Kurtzberg et al., 1979; Parmelee, 1975; Parmelee & Harber, 1973; Piper et al., 1985; Touwen, 1980). This issue needs to be carefully investigated in order to allow improvement for the developmental outcome of young preterm infants. Recent studies have investigated the impact of preterm birth on later development by examining different groups of preterm infants, instead of comparing their performance with that of full-terms (Piper et al., 1989; Piper et al., in press). This procedure is a step towards a better understanding about the impact that medical technological advances, such as neonatal intensive care units, are having on infants' development, by increasing the life expectancy of very young preterm infants. The present study proposed to examine the the effect of preterm birth on specific aspects of development such as early visual orientation and later eye-hand performance.

Infants' Visual System

Ffooks (1969) defines the visual process as "the reception of information by the retina and the transmission of that coded information along the optic nerve and radiations to the cerebral cortex". In infancy the visual process is in a continuous state of development and interacts with the development of all other motor and sensory systems. Thus, the visual system has an important role in the infants' interaction with the environment (Brazelton et al.,1966).

Vision is one of the most investigated sensory systems. Gorski et al. (1987) describe this system as an interesting paradox. Although the visual system is the least well-developed of any sensory system at birth, and the last to start functioning, it is extremely important in the infant's interaction with the environment. In order to understand the relationship between preterm birth and visual performance, it is essential to study the development and maturation of the structures underlying the processing of visual information.

A) Development and Maturation of the Visual System

The structures of the visual system develop at different periods during gestation and throughout the first years of life.

The retina differentiates during the first trimester of gestation (Gorski et al., 1987). It consists of the fovea in the central region and the periphery. The fovea is comprised of cones that mediate details and color vision (Gorski et al., 1987). Cones within the central retina do not attain full development until at least four months post term (van Holf-van Duin & Mohn, 1984). The periphery of the retina consists mainly of rods that are responsible for the detection of brightness changes and movement (Gorski et al., 1987). The rod cells are the last to develop in utero but at birth are fully functional (Timor-Tritsch, 1986). Differentiation of the foveal region in utero occurs first; however, at birth this region is quite immature, whereas the periphery of the retina is adult-like (Abramov et al., 1982).

The epithelial adhesion between the eyelids breaks down by the end of the fifth fetal month, so the eyes of preterm infants can be opened by 26 weeks gestational age. However, preterm infants usually keep their eyes closed in the first few weeks of life (Timor-Tritsch, 1986). This implies that pattern vision is unlikely before 28 weeks gestation. The pupillary light response is generally present, although slow, by 31 weeks (Finnstrom, 1971), but the dilatory muscle of the pupil is still not totally functional by term (van Holf-van Duin & Mohn, 1984). When considering refraction, van Holf-van Duin & Mohn (1984) report that normal 28 week infants seem to be myopic (image of objects are focused in front of the retina, meaning that infants focus better on near objects; Gouras, 1985), whereas in the last few weeks before term they seem to be hypermetropic (image of objects are focused beyond the retina, allowing better focusing on distant objects; Gouras, 1985). Eye movements, important for tracking moving objects in the visual field, begin in the human fetus between 16 and 18 weeks post-menstrual age and by 20 weeks eye movements become more rapid. However, there is a gradual decline in the percentages of both rapid and slow eye-movements between 32 and 40 weeks gestation (Prechtl & Nijhuis, 1983). Thus, the oculomotor system has been active for about five months prior to the first visual input at term.

The occipital cortex begins to myelinate during the sixth fetal month, and the calcarine portion of the occipital cortex is well myelinated at birth (Brazelton et al., 1966). Myelinization of the optic nerve was first observed in the seventh month of fetal life (Nakayama, 1967). This process appears to be hastened by light exposure (Mellor & Fielder, 1980). Magoo & Robb (1981) describe the process of myelination from the optic tract reaching the globe by term, and significantly increasing in sheath thickness during the first two years of life. The frontal eye fields are not myelinated in the newborn infant. In the adult frontal eye fields are known to contribute to the initiation of voluntary fixation (Gouras, 1985). It is plausible to think that the immaturity of these structures and pathways at birth will affect the optimal performance of infants' visual abilities. According to Grafstein (1963), myelination is not necessary for function but it increases the speed of conduction. It has been suggested that with the influence of light, a preterm infant at 40 weeks post conception will have more advanced myelination of their visual structures than a newborn full-term infant (Hoyt et al., 1982). This suggestion is in agreement with the "nurture" argument described earlier, specially with those investigators who contend that the extrauterine environment has a positive effect on preterm infants' visual functioning (Baraldi et al., 1981; Kopp et al., 1975; Palmer et al., 1982).

Considerable changes occur in major central structures of the visual pathway, such as the lateral geniculate nucleus and the primary visual cortex, during the postnatal period. The lateral geniculate nucleus of the thalamus is the intermediator between the eye and the visual cortex. During fetal as well as early postnatal life the lateral geniculate nucleus neurons show immature features such as numerous dendritic and somatic spines, which will disappear by nine months of age (van Holf-van Duin & Mohn, 1984). In the visual cortex, dendritic growth of neurons starts at twenty-five weeks gestation, is very active around term and continues during the first year postnatal life (van Holf-van Duin & Mohn, 1984).

In early development, the major structural changes within the visual system are followed by functional changes. Most visual functions show changes during the first few months after birth. Although several structures are quite immature at term, they are functional at birth and tend to improve with subsequent maturation. Visual accommodation, defined as the ability to focus objects, is poor in the first month of life, but it improves by the third month, along with the maturation of the pupillary system, the ocular muscles and lens. Acuity is the ability of the visual system to detect various patterned information. It is also poor at birth but shows rapid improvement over the first six months of life, along with the maturation of the foveal region of the retina. Unlike older infants, newborn infants visually track objects by performing saccadic eye movements. By four months of age smooth pursuit eye movements improve along with the maturation of the oculomotor system and thereafter saccades are no longer present in smooth tracking (Gorski et al., 1987).

B) The Effect of Prematurity on the Development of Visual Functions

As has been discussed earlier, the role prematurity plays in development has been the object of intense controversy and investigation. The influence of prematurity on development of visual functions is one component of this controversy particularly pertinent to this project.

In 1981, Friedman et al. reported that the visual system develops throughout pregnancy, and structural changes occur as late as the ninth month of gestation. This structural immaturity results in functional immaturity at term, as described in the previous section. Function is improved with subsequent development. Consequently, Friedman et al. (1981) suggested that the visual system is adversely affected by preterm exposure to the extrauterine environment. As stated earlier, van Holf-van Duin & Mohn (1984) reported that preterm infants are known to have a high incidence of visual problems, and Rossetti (1986) agreed that visual disturbances are present in 44% of the high-risk population, which includes a large number of preterm infants. Indeed, infants born prematurely are exposed to visual stimulation during a period which is unavailable to full-term infants.

The investigation of the effects of extrauterine environment on the development of the newborn by comparing the performance of infants born at term with preterm infants, both usually at 40 weeks gestation, has produced controversy (Cioni et al.,1986). Some studies stress the similarities, others emphasize the differences between preterm and full-term infants.

Ferrari et al. (1983) reported poorer performance by low-risk preterm infants in comparison with full-term newborns, in the areas of visual orientation and alertness, as assessed by the Brazelton Neonatal Behavioral Scale (Brazelton, 1984). Among the infants' behavioral repertoire they recorded inferior performance of visual and auditory orientation, inferior motor performance and poorer regulation of alertness state. Morante et al. (1982) examined pattern vision in preterm and full-term infants using a preferential looking technique. This study was based on the premise that infants prefer to fixate on a patterned visual stimulus than on a homogeneous stimulus. They found that preterm infants at 40 weeks post conception had poorer pattern preferences than full-tenn infants.

Allen & Capute (1986b) found no differences between premature and full-term infants on three visual measures: 1. response to blinking and habituation to light, 2. blinking to a threatening gesture and 3. optokinetic nystagmus. No differences in pupil response, head-turning and blinking to light between preterm and full-term infants at 40 weeks were also reported by Robinson (1966).

Other investigators have found that preterm infants have superior visual performance when compared with full-terms on a forced preferential looking task (Baraldi et al., 1981) and that they show longer visual fixation periods (Kopp et al., 1975). Also, Palmer et al. (1982) reported better visual orientation and alertness state among preterm infants in comparison to full-terms, both at 40 weeks gestation. And, as stated previously, Hoyt et al. (1982) suggest that early visual experience of preterm infants in the period from birth to term may lead to a slight acceleration in the development of the visual system. Paludetto et al. (1982) suggested that the extrauterine environment could have a specific impact on those visual responses which can be influenced by the bright light to which the infants are exposed in the nursery, such as the visual orientation responses measured by the Brazelton Neonatal Behavioral Assessment Scale. Thus support exists for both sides of this argument and it remains unclear whether early exposure to light has a beneficial or harmful effect on infants' visual system.

Another aspect of this controversy relates to the infants behavioral state. The autonomic nervous system mediates the infants' response to the external environment and is responsible for regulating the organization of behavioral states in the infant, among other physiological functions. It has been documented that an infants' behavioral state has an impact on their visual fixation responses (Boismiere, 1977; Hack et al., 1976; Hack et al., 1981). A study by Moseley et al. (1988) suggested that the increase in intensity of illumination within the NICU environment tends to have a deleterious effect on both organization of behavioral state and amount of eyelid opening among preterm infants. Thus, the extrauterine visual stimulation experienced by preterm infants may indirectly affect their ability to respond to a visual stimulus by influencing the infants' behavioral state.

In summary, despite being the last of the sensory systems to have its functional onset, the visual system is very important for interaction with the environment. Consequently, several investigators have studied the impact of preterm birth on the development of the immature structures and functions of the visual system. Although the visual abilities of preterm infants have been widely investigated using different methodologies, no consensus has yet been formed.

C) Assessment Techniques to Measure Visual Function

Most investigators agree that the assessment of visual function in the newborn is an essential part of the neurological examination and is indicative of central nervous system function (Brazelton et al., 1966; Kopp et al., 1975; Morante et al., 1982; Placzek et al., 1985). More specifically, Brazelton (1984) argues that the ability to fixate and follow a visual stimulus can be seen in alert preterm and full-term infants, and any interference with optimal central nervous system function in these infants may reduce their ability to elicit these integrated visual responses. However, he also contends that although the elicitation of visual focusing and tracking has been found to be predictive of later normal central nervous system function, the lack of response is not necessarily an indicator of future dysfunction.

One of the most important functions of the visual system is to detect patterned information (Gorski et al., 1987). Pattern detection refers to the ability to perceive that a stimulus is patterned in contrast to being unpatterned or uniform, and is often assessed using tests of visual acuity (Banks & Salapatek, 1983; Gorski et al., 1987). The three commonly used techniques to assess visual acuity in the neonatal period, are: optokinetic nystagmus (OKN; Gorman et al., 1957), preferential looking (PL; Atkinson et al., 1977; Fantz, 1963; Teller et al., 1974;), and visually evoked potential (VEP; Norcia & Tyler, 1985). The investigations using all of these techniques have indicated that the visual acuity of infants increases between birth and six months (Dobson & Teller, 1978).

OKN is defined as "the involuntary series of eye movements elicited by a succession of objects passing across the visual field" (Dobson & Teller, 1978, p. 1469). The eye movements present in OKN consist of two parts: a slow fixation phase, when the eyes follow the stimulus, and a fast corrective phase in the opposite direction (Gorman et al., 1957). In this technique, acuity is measured binocularly while the infant is positioned supine in a crib looking up at a canopy of black and white stripes. The stripes move in 180 degree-arc across the infant's visual field, and the evaluator looks for the smallest stripe width which elicits OKN (Hoyt et al., 1982). This technique requires that the infant be awake with open eyes.

The preferential looking technique was developed by Fantz (1963) on the assumption that infants fixate on patterned surfaces more than homogeneous surfaces. Pattern preference appears after 34 weeks gestation (Dubowitz, 1979). This technique requires the infant to fixate differentially on various pair of stimuli presented within the visual environment (Dobson & Teller, 1978). The reflection of the visual stimulus in the infants' pupil is observed and both the number of times and duration of fixation on the visual object are recorded. The preferential looking technique is the most common procedure used to document the visual acuity of young infants and some interesting findings have been reported. Using the preferential looking technique, Fantz (1963) showed that during the early months of life infants have greater visual interest for patterns than for plain colors, and their interest increases if the pattern is similar to that of a human face. In 1977, Atkinson et al. reported that infants show a preference for moving versus stationary patterns. This procedure has been used to assess preferences in full-terms as well as in preterm infants (Dubowitz et al., 1980; Morante et al., 1982).

Visual evoked potential (VEP) consists of "monitoring the activity of the visual cortex in response to visual information processed by the retina and by the visual pathway" (Norcia & Tyler, 1985, p. 1399). It is recorded by placing electrodes on the scalp over the occipital region, where the visual cortex is located. The VEP technique shows part of the activity of the visual cortex in response to visual information processed by the retina (Norcia & Tyler, 1985). Some investigators prefer this technique to evaluate the visual system because it is not dependent upon a motor response (Hrbek & Mares, 1964; Hrbek et al., 1973; Norcia et al., 1987; Watanabe et al., 1972). VEPs can be elicited by either a flash of light or by visual fixation on patterned stimulus. Evoked potential is not a common procedure to measure visual abilities in young infants since it requires the child to be immobile and sedated.

In addition to these techniques, function within the visual system is also assessed through clinical procedures (see Table 1). For example, the pupillary light response indicates the functioning state of afferent and efferent pathways, and it is usually present by 31 weeks gestation (Robinson, 1966). The blink to light and to threat are both learned reflexes; the first may be attained by 30 weeks gestation, but the later develops in normal full-term infants from 16 weeks postnatally (Hoyt et al., 1982). Head turning to light, which is a gross measure of visual acuity, begins between 32 and 36 weeks gestation (Finnstrom, 1971). The ability to fixate and follow a target is also known as visual orientation and is one of the principal tests employed to assess central visual function in infants (Dubowitz, 1979).

Visual orientation has been used to document the visual function of preterms (Dubowitz, 1979) and full-term neonates (Brazelton, 1984). Dubowitz (1979) argues that by 34 weeks gestation preterm infants show maturity of visual orientation responses which are comparable to those seen in full-term infants. Both Brazelton (1984) and Dubowitz (1979) agree that visual orientation responses in the newborn preterm and full-term infants can be used not only as a parameter of visual function but also of neurological maturity. Visual orientation has been used as a means of comparing the responses of preterm with full-term infants, but the literature is controversial. Forslund & Bjerre (1983) reported that by term, preterms showed significantly better ability to focus and follow a red ball than full-term infants. Conversely, Ferrari et al. (1983) found inferior visual orientation performance by preterms when compared with full-term neonates. Visual orientation responses are known to be influenced by infants' behavioral state (Gorski et al., 1987). According to Hack et al. (1976) visual fixation requires an increase in infants' alertness and attentiveness, and is often followed by other behaviors such as eye opening, interruption of sucking, and decrease in general motor activity. There is a suggestion that early visual orientation may be related to later cognitive functioning. According to Wolff (1965), because of the complexity in the ability to visually follow an object, there may be a functional continuity between early visual orientation responses and cognitive function in the child and adult.

TABLE 1

Maturation of Visual Abilities by Gestational Age

GESTATIONAL AGE	VISUAL ABILITIES
30 weeks post-conception	BLINK TO LIGHT
31 weeks post-conception	PUPILLARY LIGHT REFLEX
32-36 weeks post-conception	HEAD TURN TO LIGHT
After 33 weeks post-conception	FIXATE AND FOLLOW A TARGET
16 weeks post-term	BLINK TO THREA

One important aspect to be considered when measuring visual performance in infants is the control of confounding parameters that can influence the results. Gestational age and behavioral state are factors that should be taken into consideration when assessing the visual system. Tilford (1976) and van Holf-van Duin et al. (1983) argued that gestational age at the time of the assessment is an important factor that may interfere with the results. They suggested that when measuring the visual acuity of preterm infants one should consider their conceptional age rather than chronological age, since acuity development in preterm infants is related to age after conception. Accordingly, Dobson et al. (1980) contend that visual acuity screening in preterm infants should be carried out following infants' post conceptional age, instead of postnatal age.

Relative to behavioral state, Brazelton et al. (1966) claimed that the alertness state of the newborn at the time of the assessment may interfere with his/her visual response. According to Wolff (1965) the state of quiet alertness, where the infant is awake, inactive and has his/her eyes opened is the ideal state to assess visual responses in infants. This behavioral state allows the infant to respond adaptively and selectively to the environment (Hack et al., 1976).

Most of the studies cited earlier accounted for gestational age by assessing the visual abilities of preterms and full-terms, both at 40 weeks gestation, and also by correcting for prematurity when following preterm infants longitudinally. However, fewer studies reported the behavioral state at the time of the assessment, and for that we may question their results.

Interaction Between Visual System and Motor Development in Infancy

Sensation and movement have been closely linked. Gesell et al. (1949) stated that the improvement of visual functions must be interpreted in terms of motor maturation as "vision and movement are components of a highly organized sensorimotor integration of stimuli in the central nervous system" (p. 54). The study of visual function has historically focused on either the medical model concerning visual acuity, or the educational model regarding visual perception (Erhardt, 1987). Recently, investigators have also focused on the visual motor coordination, specifically the association between eye and hand, which influences the development of both prehension and vision as well as the development of exploratory functions (Erhardt, 1987).

Eye-hand coordination is known to be an integrated sensorimotor skill and has been defined as "the ability of hands and fingers to go exactly to the places where the eyes inform the brain that they should go" (Ayres, 1979, p. 64). It is known that the visual motor coordination required for reaching towards an object requires the visual perception of the object and motor abilities as well as the ability to associate visually perceived information with motor behavior (Lockman et al., 1984).

In the past investigators were interested in the neonate's reflexive patterns as a critical tool in assessing the integrity of the central nervous system (Allen & Capute, 1986). The coordination between visual and prehensile activities was thought to develop only gradually in ontogenesis, as an outcome of reflex activity (Gesell & Amatruda, 1964; Piaget, 1952). For example, the voluntary reaching and grasping which are necessary for the infant manual exploration of objects was believed to develop from the rudimentary proprioceptive grasp reflex. This traditional reflex-to-voluntary behavior model of development has been questioned and an alternative hypothesis suggested. This hypothesis proposes that antecedents of voluntary behavior are distinct from reflex functions (McDonnell, 1979). This model has given support to studies investigating reaching abilities of newborn infants (Field, 1977; Hofsten, 1982; McDonnell, 1979). Hence, researchers are now turning their attention to precursors of volitional behavior in infancy.

During the past two decades, research has demonstrated that infants' discriminative capacities are more developed during the first year of life than had previously been thought. Hofsten (1982) found in the newborn a rudimentary form of eye-hand coordination which has an attentional function, rather than a manipulative function. According to the findings reported in the study, there is an increased amount of forward extended arm-hand movements when the infant visually fixates an object, suggesting the existence of a close relationship between arm-hand activity and visual fixation. Hofsten suggested that a coordination between eye and hand exists in the newborn, and although it is evident that the catching, grasping, and manipulation functions of eye-hand coordination are not fully developed in the neonate, he/she has the ability to direct his/her eyes and hands towards the external object that was visually detected. McDonnell (1979) looked at patterns of eye-hand coordination in the first year of life and reported that hand movements in infants under eight weeks of age are progressively coordinated with visual stimuli. The observations are also consistent with the hypothesis that "eye-hand activities may emerge concurrently with the maturation of reflex functions, rather than in transition from reflexes" (McDonnell, 1979, p. 255).

Recent investigations suggest that premature infants differ among themselves and also from full-term infants in their performance on fine-motor abilities. Field et al. (1981) followed a group of preterm infants with respiratory distress syndrome. At eight months corrected age they reported delays on items requiring fine-motor skills, as measured by the Bayley Mental Scale. Similarly, Piper et al. (in press) compared two gestational age groups of neurologically normal preterm infants at eight and 12 months chronological and corrected ages. Even when correction for prematurity was performed, infants born at very early gestational ages (less 32 weeks gestation) differed significantly in their fine-motor development when compared with preterm infants born at older gestational ages (32-36 weeks gestation). Ungerer & Sigman (1983) observed that preterm infants performed significantly poorer than full-term infants on items concerning visual information-processing and/or perceptual-motor skills, at three years of age. Their findings suggest that impairments in visual processing may underlie delays in sensorimotor functioning that are identified in later school years. Ross (1985) used the Bayley Scales to compare the performance of preterm with full-term infants, at one year corrected age. She noted that premature infants were less likely to succeed on items testing eye-hand coordination, imitation, and vocalization. These deficits may be seen as early precursors of the difficulties in perceptual-motor abilities that have been found in school age children who were born prematurely (Hunt, 1981; Siegel, 1983).

Visual fixation by preterm infants, at term, has been investigated as a potential predictor for later developmental outcome. Sigman & Beckwith (1980) examined the relationship between preterm and full-term infants' visual fixation at term with caregiver-infant interaction at one month and with developmental outcome at two years, as measured by the Bayley Mental Scale. Surprisingly, there was a significant negative correlation found between the amount of early visual fixation and the scores on the Bayley Scale, at two years. This negative relationship was reported among the preterm group but not among the full-term infants. Besides attributing the negative relationship to a weakness in the study methodology, the authors also question whether sustained fixation should be considered as optimal visual response or if it simply reflects the slower processing of young preterm infants. Further longitudinal studies are needed to explain the poor developmental performance that has been reported in this and other investigations, among preterm infants.

As preterm infants have been found to show poor fine-motor performance at one year, it is now time to investigate this problem more carefully, in an attempt to identify early predictors that might account for this specific poor performance. It is still unknown whether the extrauterine experience or the early visual stimulation received from the environment can account for the later fine-motor difficulties reported among preterm infants. Therefore, the relationship between preterm birth, early visual processing, and later fine-motor performance should be examined more carefully.

Summary

In summary, some differences in the neurobehavioral performance can be identified when preterm infants are compared with full-term infants. Thus, preterm infants should be considered unique with their own abilities and patterns of development rather than being classified as abnormal when compared with full-term newborns. The role of the prolonged extrauterine environment in explaining these differences in development is still unclear.

Studies of the development of preterm infants have included descriptions of the maturational process of their visual functions. Adequate visual abilities of the neonate are viewed as positive evidence of the integrity of the central nervous system. As vision and movement seem to interact early in the process of development, Hoyt et al. (1982) suggest that visual impairment in infancy may result in maturational delays of motor skills and socialization.

During the first two years of life the child interacts with the environment through his/her sensations and motor responses, with the emphasis being on sensory, motor, and manipulative experiences. Thus, eye-hand coordination, as part of the child's sensorimotor repertoire, is an important milestone in the child's early exploratory skills.

Infants born before term show lowered performance on items measuring mental and fine-motor abilities, specially at school age. Preterm infants have been investigated for their abilities at birth and have been followed longitudinally in an attempt to identify early indicators of their "non-optimal" fine-motor outcome. Early identification of potential difficulties in specific areas of development may be useful in signaling the need for careful observation of these children's development, as well as in suggesting the need for early remediation of identified and associated difficulties. Thus, given a potentially positive relationship between early visual functioning and subsequent fine-motor ability, early visual-manipulative-related activities might be emphasized during intervention in order to minimize emergence of fine-motor problems later on the development.

As described by Ayres (1979), the sequence of development follows a "building blocks" pattern where primary levels of organization become the basis for more complex and mature acquisitions. Information concerning the possible relationship between early visual performance in preterm infants and later, more organized and complex functions, such as eye-hand abilities is lacking. The investigation of such relationship might explain some aspect of the poor fine-motor performance reported among preterm infants.

CHAPTER III

METHODS AND PROCEDURES

Study Design

A prospective correlational study design was used in order to gather information about the relationship among the variables being studied (Smith & Glass, 1987). A prospective study has a number of advantages when compared with a retrospective design; in particular it decreases the possibility of subjective bias in obtaining the information (Lilienfeld & Lilienfeld, 1980).

Study Participants

The present study utilizes secondary data from the study entitled "Impact of preterm birth on the neuromotor development of the premature infant", whose primary investigator is Dr. M. C. Piper. The data were collected between 1985 and 1987. The objective of the original project was to evaluate the impact of preterm birth on the neuromotor development of premature infants, according to their adjusted and chronological ages.

The subjects of this study were preterm infants less than 36 weeks gestation at birth who have received neonatal care at the neonatal intensive care unit of the University of Alberta Hospitals, in Edmonton. Infants with congenital abnormalities were excluded. Gestational age was determined from maternal history of the last menstrual period and confirmed by early ultrasound if available, or by the Dubowitz technique (Dubowitz et al., 1970).

Infants with informed parental consent (Appendix A) were assigned to one of the two preterm groups, according to their gestational age at birth:

Group 1: Infants born at less than 32 weeks of gestation;

Group 2: Infants born between 32 and 36 weeks of gestation.

Data Collection Procedure

The present study considered data collected from assessments performed on all participating infants according to the following schedule:

1. At 40 weeks gestational age: The Neurological Assessment of the Preterm and Full-Term Newborn Infant (Dubowitz & Dubowitz, 1981; Appendix B), which includes an item to measure visual orientation;

2. At 12 months corrected age: The Griffiths Mental Developmental Scales (Griffiths, 1954; Appendix C), which includes a subscale to measure eye-hand performance.

3. At 18 months corrected age: The incidence of cerebral palsy and other neuromotor disorders was determined through a neurological examination performed by a developmental pediatrician. The Neurological Examination of the Collaborative Perinatal Project (Hardy et al., 1979) was used to assess the incidence of neuromotor disorders in this cohort of infants.

Corrected age was determined by subtracting the number of weeks the infant was born before term from his/her chronological age.

The first two assessments were performed by one therapist who was pretrained in the administration of the assessment tools and who was "blind" to the gestational age at which the infant was born in order to avoid any bias concerning the his/her general performance. The developmental pediatrician who performed the neurological assessment at 18 months corrected age was also kept "blind" to the children's gestational age at birth as well as to their medical histories.

Measures

A) The Neurological Assessment of the Preterm and Fullterm Newborn Infant

The Neurological Assessment of Preterm and Full-Term Newborn Infants was designed by Dubowitz & Dubowitz (1981) in an attempt to combine both neurological and neurobehavioral examinations into one practical and objective evaluation that can be performed within a short period of time. This tool is applicable for full-term as well as preterm infants and is also used for sequential examinations of preterm infants.

The assessment tool consists of two items on habituation (auditory and visual); 16 items on posture, movement, and tone; five primitive reflexes; and seven neurobehavioral items. There are also some general observations such as eye movements and character of cry. Responses are not graded as normal or abnormal; rather, each item has a maximum of five grades of responses.

Many items have been borrowed from previous assessments and therefore, the content validity has been established previously (Pelletier & Lydic, 1986). Tests of predictive validity have demonstrated a good correlation between 40 weeks postmenstrual age and neurological outcome at one year (Dubowitz et al., 1984).

Although no reliability studies have been conducted, the authors note in the manual that the assessment has shown good inter-observer correlations between pairs of observers examining the same baby independently (Dubowitz & Dubowitz, 1981). Since this test is not norm-referenced, norms are not available.

Visual performance was measured with the visual orientation item from the neurobehavioral section of this neurological assessment. The selected item was borrowed originally from the visual function part of the Neonatal Behavioral Assessment Scale (Brazelton, 1984). In this item the infant is assessed for his/her ability to focus and fixate on a red woollen ball, and to track (follow) it. Five responses are possible for this item:

1. The infant does not focus or follow stimulus.

2. Stills; focuses on stimulus; may follow 30° jerkily; does not find stimulus again spontaneously.

3. Follows 30-60° horizontally; may lose stimulus but finds it again. Brief vertical glance.

4. Follows with eyes and head horizontally and to some extent vertically with frowning.

5. Sustained fixation; follows vertically, horizontally, and in circle.

The responses of the visual orientation item require greater levels of maturation of the visual system as they increase from response 1 to response 5, according to the grading description. The visual orientation of the preterm infants was classified as either "optimal performance" or "non-optimal performance". A grade equivalent to columns 3, 4 or 5 was defined as "optimal performance". A score on columns 1 or 2 was considered as a "non-optimal performance". These criteria were based on the findings that the score of 3 was the most frequent visual orientation response and therefore it was considered an "optimal" response and used as a baseline; the scores which required less mature response (1 and 2) were then considered "non-optimal". Also, according to Dubowitz & Dubowitz (1981) most preterm infants can be expected to track horizontally, vertically and in circle at 40 weeks post conception.

B) The Griffiths Mental Developmental Scales

The Griffiths Mental Developmental Scales were designed to assess the level of mental development of babies and young children from birth to eight years of age. The Scales provide developmental quotients and mental ages for five developmental domains: locomotor, personal-social, hearing and speech, eye-hand, and performance, as well as an overall development quotient. Each subscale contains 52 graded items for the first two years of life based on three items for each month of life in the first year, and two items for each month in the second year. This tool was standardized on British children (Griffiths, 1954). A further use of this assessment has been to evaluate the outcome of intervention programs (Smith et al., 1980).

The eye-hand subscale was used to measure eye-hand performance of the preterm infants at 12 months of age. Inter-rater reliability of the eye-hand and the performance subscales have been found to show greater consistency (r falling between 0.6 and 1.0) than the other subscales in this assessment (Smith et al., 1980).

Developmental scores are translated into mental ages and quotients for the eye-hand subscale. The mental age for each infant is given by multiplying by five the total score of items passed by the child in the first year of life (as there are roughly five weeks in each month). The result is divided by three (as there are three items in the scale for each month during the first year of life). Because some children may pass items for the second year of life, mental ages are calculated separately for the second year of life, and the results are added to the first year, to give the mental age for the subscale.

$$\text{Mental Age 1 (M.A. 1) for the 1st year} = \frac{\text{items passed x 5}}{3} \text{ weeks}$$

$$\text{Mental Age 2 (M.A. 2) for the 2nd year} = \frac{\text{items passed x 5}}{2} \text{ weeks}$$

$$\text{M.A.} = \text{M.A.1} + \text{M.A.2}$$

The developmental quotient for the subscale of eye-hand (DQ E-H) was obtained by multiplying the infant's mental age by one hundred and dividing the quotient by the child's corrected age (C.A.) at the time of the assessment.

$$\text{DQ E-H} = \frac{\text{M.A. X 100}}{\text{C.A.}}$$

A developmental quotient equal to or greater than 100 is considered to be normal.

C) Neurological Examination of the The Collaborative Perinatal Project

The Neurological Examination of the Collaborative Perinatal Project involves a complete pediatric examination, including a detailed assessment of neurological function and developmental skills (Hardy et al., 1979). A judgement is made as to whether the child is normal, suspect, or abnormal in each of two categories, named neurological status and non-neurological status, which includes all other aspects of the pediatric evaluation. For this study, the outcome used was neurological status.

Ethical Considerations

1. The parents of all infants were required to sign an informed consent form (Appendix A) prior to data collection procedure.

2. Confidentiality is guaranteed by reporting each subject with a given identification number, rather than by name. Only the project coordinator and the principal investigator of the original research have access to a master list which relates study numbers to names. All children will remain anonymous throughout the study.

3. Data will be reported as group data in any presentation of the results found in this study.

Limitations of the Study

A) Methodological Limitations

1. This is an observational study and for that reason no assumptions about cause and effect relationships between independent variables are warranted.

2. Eye-hand coordination is functionally important at preschool age and consequently some aspects that might be not apparent at 12 months may appear later in fine-motor development.

3. This is a secondary data study and for that reason no major changes can be made concerning the data collection procedure.

4. The assessment tools used in this study have not been completed validated. However, other authors have used them with the preterm population (Dubowitz et al., 1980; Piper et al., in press).

5. The allocation of preterm infants to gestational age groups and to visual orientation categories was an arbitrary procedure and they may not translate the optimal way of examining difference between groups.

B) Limitations in Data Collection

1. Infants were assessed on only one occasion. The scores obtained may be affected by factors such as test environment, time spent to arrive at the place of the test, time since last fed, as well as some physiological needs of the child.

2. The examiner's face as well as any auditory stimulation may have distracted the infant and interfered with the response to the visual orientation assessment.

3. The reliability coefficient for the present data is unknown.

Data Analyses

Mann-Whitney U test was used to test for the difference between the two groups of infants born at different gestational ages (less than 32 weeks; between 32-36 weeks) in their actual visual orientation scores from the Neurological Assessment of the Preterm and Fullterm Infant (1, 2, 3, 4, and 5). Chi-Square analysis was applied to test whether the two gestational age groups of infants differed according to their visual orientation performance at 40 weeks post conception (optimal; non-optimal).

Jaspen's M coefficient of multiserial correlation was used to examine the strength of the relationship between the visual orientation scores of preterm infants at 40 weeks post conception (1, 2, 3, 4, and 5) and their eye-hand developmental quotients at 12 months corrected age. The Jaspen's M is the appropriate correlation coefficient to examine the association between one ordinal variable, in this case visual orientation scores, with another variable from an interval scale, such as the eye-hand developmental quotients (Champion, 1981). Unpaired t-test was the analysis used to test the difference between the two groups of infants classified according to visual orientation at 40 weeks post conception (optimal; non-optimal), on their eye-hand developmental quotients at 12 months corrected age. This analysis was also used to test the difference between the two gestational age groups (<32 weeks; 32-36 weeks) on their eye-hand developmental performance at 12 months corrected age.

As recommended by Kerlinger (1986), multiple regression analysis is the appropriate procedure for factorial designs having unequal number of cases in each cell. Stepwise multiple regression analysis was employed to test which variables (gestational age at birth; visual orientation at 40 weeks post conception; neurological status at 18 months corrected age) accounted for the most variance in eye-hand developmental quotients at 12 months corrected age.

The statistical analyses were initially carried out with the total sample of preterm infants (N= 73). Subsequently, the same analyses were performed with the 45 infants who were assessed as being neurologically normal at 18 months corrected age. This procedure minimizes the bias associated with including those infants who were either neurologically suspicious or abnormal.

All statistical analyses were tested at the 0.05 level of significance.

CHAPTER IV

RESULTS

CHARACTERISTICS OF STUDY SAMPLE

Initial data were collected on 120 preterm infants. The eighteen month neurological assessment was completed on 73 of the original 120 infants. This study has analyzed the data from those 73 infants.

Of the 47 dropouts, two infants died and the remaining infants either moved or lived too far away to return for the 18 month assessment. Most of the infants who were not from Edmonton were born in small towns within the province of Alberta. After being born, they were transfered from their towns to the University of Alberta Hospital, mainly because of postnatal complications and absence of appropriate medical resources in their towns. Therefore, from the original 120 infants, the 47 dropouts, as a group, are those infants who are most likely to have had serious perinatal problems.

Of the 73 infants who comprised the study sample, 38 were males and 35 were females. These infants were then assigned to one of two groups according to gestational age (G.A.) at birth: less than 32 weeks gestation (n= 34), and 32-36 weeks gestation (n= 39). The frequencies of gestational ages, birthweights, and gender for each of the two gestational age groups are provided in Table 2.

The neurological outcomes at 18 months corrected age for infants in the two gestational age groups are documented in Table 3.

The frequencies of the visual orientation scores for the 73 infants, as assessed with the Neurological Assessment of the Preterm and Fullterm Newborn Infant (Dubowitz & Dubowitz, 1981) at 40 weeks post-conceptional age, are illustrated in Figure 1. The visual orientation scores were then combined and classified into two categories: "non-optimal" (scores 1 and 2; n=18), and "optimal" (scores 3, 4, and 5; n=55). See the Methods section (p. 29) for the rationale for combining groups.

TABLE 2

Frequencies of Gender, Gestational Age and Birthweight by Gestational Age Group

CHARACTERISTIC	GESTATIONAL AGE GROUP			
	< 32 WEEKS(n=34)		32-36 WEEKS (n=39)	
GENDER				
MALE	16	(47.06%)	22	(56.41%)
FEMALE	18	(52.94%)	17	(43.59%)
GESTATIONAL AGE				
25-27 WEEKS	9	(26.47%)	-	
28-29 WEEKS	15	(44.12%)	-	
30-31 WEEKS	10	(29.41%)	-	
32-33 WEEKS	-		19	(48.72%)
34-36 WEEKS	-		20	(51.28%)
BIRTHWEIGHT				
< 750 gm	2	(5.88%)	-	
750-1000 gm	9	(26.47%)	-	
1001-1500 gm	16	(47.06%)	4	(10.26%)
1501-2500 gm	7	(20.59%)	32	(82.05%)
> 2500 gm	-		3	(7.69%)

TABLE 3
Neurological Outcome at 18 Months According to Gestational Age Groups

NEUROLOGICAL OUTCOME	GESTATIONAL AGE GROUP < 32 WEEKS(n=34)	32-36 WEEKS(n=39)
NORMAL	18 (52.94%)	27 (69.23%)
SUSPICIOUS	8 (23.53%)	11 (28.21%)
ABNORMAL	8 (23.53%)	1 (2.56%)

INFERENTIAL ANALYSES

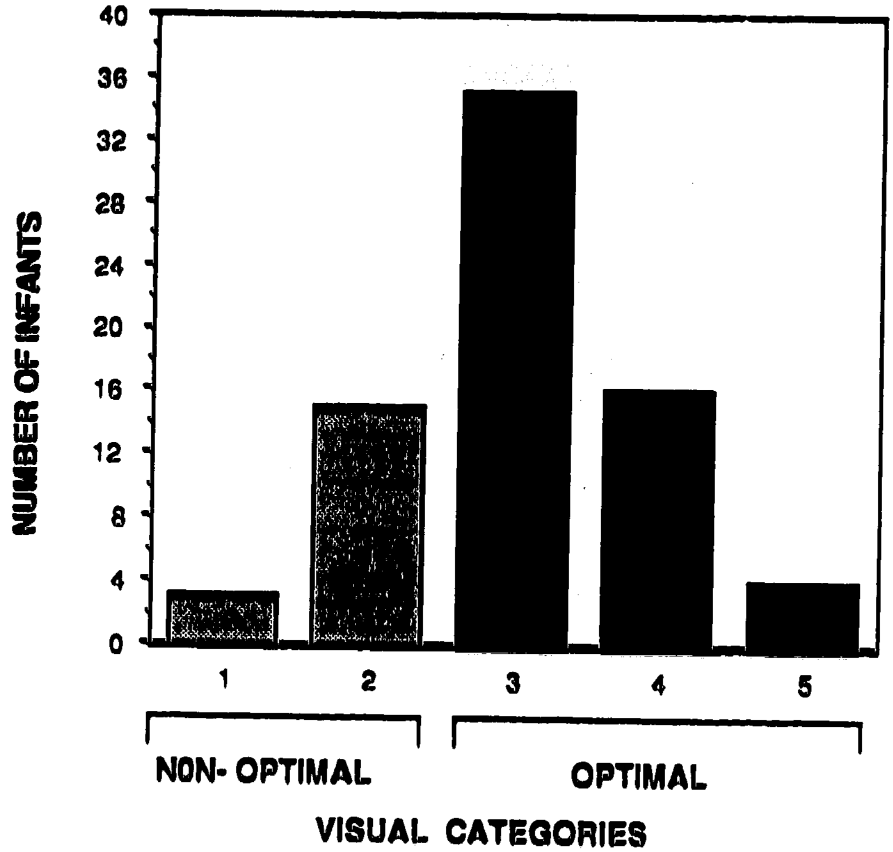
I. Comparison of G.A. groups on visual orientation at 40 weeks PCA

The two gestational age groups (<32 weeks; 32-36 weeks) were compared on their visual orientation scores at 40 weeks post-conceptional age (PCA), by first conducting a Chi-Square analysis. For the Chi-Square analysis, the visual orientation scores were combined into two categories: "non-optimal" (scores 1 and 2; n= 18), and "optimal" (scores 3, 4, and 5; n=55). The observed frequencies varied significantly (p= 0.049) from the expected frequencies. Infants born 32-36 weeks gestation were more likely to perform "optimally" than infants less than 32 weeks gestation at birth. Conversely, infants born less than 32 weeks gestation were more likely to perform "non-optimally" than infants 32-36 weeks gestation at birth. See Table 4 and Figure 2.

A Mann-Whitney U test was then conducted to compare the two gestational age groups (<32 weeks; 32-36 weeks) on the actual scores obtained on the visual orientation item (1, 2, 3, 4, or 5). The Mann-Whitney U is known to be a powerful non-parametric test of significance for difference between two independent groups, on an ordinal characteristic, such as the visual orientation scores (Champion, 1981). Infants born

FIGURE 1

Frequency of Visual Orientation Scores



Legend for Visual Orientation Scores:
1= The infant does not focus or follow stimulus
2= Stills; focus on stimulus; may follow 30° jerkily; does not find stimulus again spontaneously
3= Follows 30-60° horizontally; may lose stimulus but finds it again. Brief vertical glance
4= Follows with eyes and head horizontally and to some extent vertically with frowning
5= Sustained fixation; follows vertically, horizontally, and in circle

TABLE 4

Comparison of Gestational Age Groups by Visual Orientation Categories

(X^2= 3.88; p= 0.049; df=1††)

VISUAL ORIENTATION CATEGORIES	GESTATIONAL AGE GROUP			
	<32 WEEKS (n=34)		32-36 WEEKS (n=39)	
OBSERVED FREQUENCIES†				
OPTIMAL	22	(64.71%)	33	(84.62%)
NON-OPTIMAL	12	(35.29%)	6	(15.38%)
EXPECTED FREQUENCIES†				
OPTIMAL	25.62	(75.35%)	29.38	(75.33%)
NON-OPTIMAL	8.38	(24.65%)	9.62	(24.67)

† Significantly different at $p < 0.05$
†† df= degrees of freedom

TABLE 5

Frequencies of Visual Orientation Scores According to Gestational Age Groups

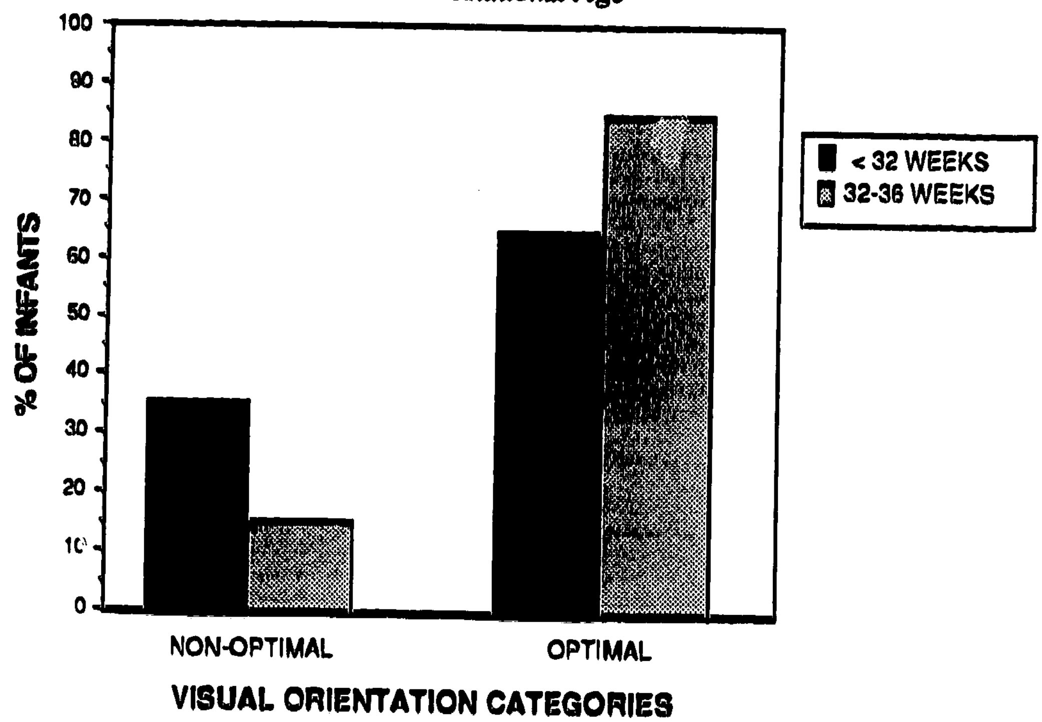
(z= -2.65; p= 0.008)

VISUAL SCORES	GESTATIONAL AGE GROUP			
	<32 WEEKS (n=34)		32-36 WEEKS (n=39)	
1	2	(5.90%)	1	(2.60%)
2	10	(29.40%)	5	(12.80%)
3	18	(52.90%)	17	(43.60%)
4	3	(8.80%)	13	(33.30%)
5	1	(2.90%)	3	(7.70%)

between 32-36 weeks gestation achieved significantly (p= 0.008) higher scores in visual orientation than the group of infants born at < 32 weeks gestation (U= 423). The results are reported in Table 5.

FIGURE 2

Observed Frequencies of Visual Orientation at 40 Weeks Post-Conception According to Gestational Age



II. <u>Comparison of Optimal/Non-Optimal Visual Orientation Categories (40 weeks PCA) on Eye-Hand Performance at 12 months</u>

Eighteen of the 73 infants (24.66%) had scores of 1 or 2 (non-optimal visual orientation), and fifty-five of the 73 infants (75.34%) had scores of 3, 4, or 5 (optimal visual orientation); see Figure 1. An unpaired t-test was conducted to compare the "optimal" infants with the "non-optimal" infants, on eye-hand performance at 12 months corrected age. Preterm infants who had "optimal" visual orientation at 40 weeks PCA did not differ significantly (p=0.67; df=71) from those who had "non-optimal" orientation, in terms of their eye-hand performance at 12 months corrected age. See Table 6 and Figure 3.

TABLE 6

Eye-Hand Developmental Quotients According to Visual Orientation Categories

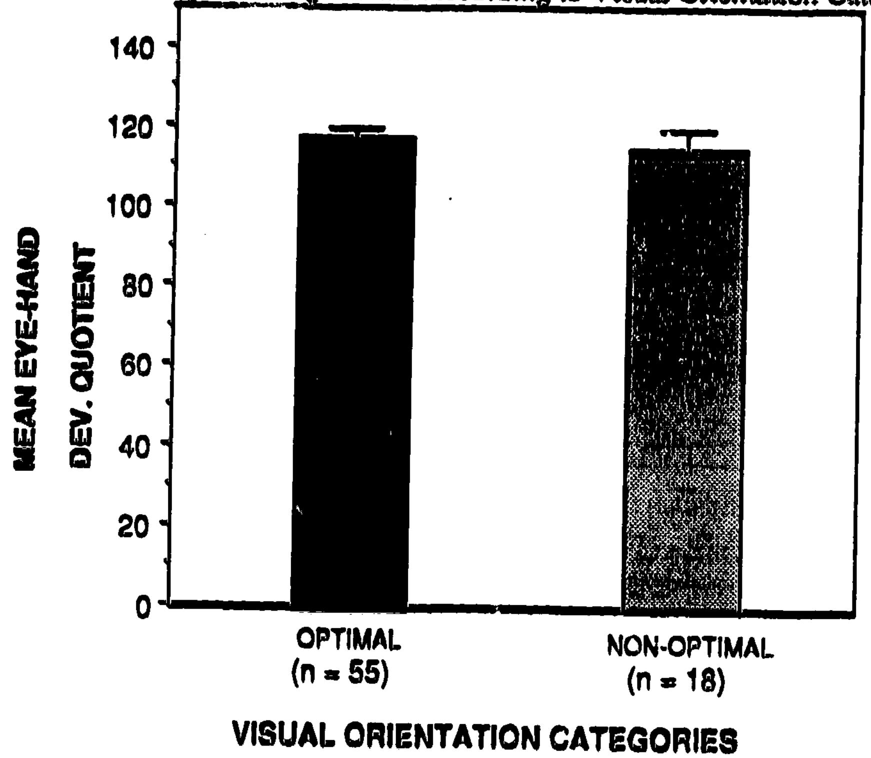
CHARACTERISTIC	MEAN EYE-HAND QUOTIENT	t VALUE (unpaired)	p VALUE (2-tail)
VISUAL ORIENTATION		-0.43	0.67
OPTIMAL (n = 55)	116.75 (SD: 17.08)		
NON-OPTIMAL (n = 18)	114.69 (SD: 18.97)		

SD: Standard Deviation

Jaspen's M coefficient of multiserial correlation was calculated to compare the actual visual orientation scores at 40 weeks (1, 2, 3, 4, and 5) with eye-hand developmental quotients at 12 months corrected age, for all 73 infants. The Jaspen's M is often used to examine the association between one variable measured in an ordinal scale, in this case visual orientation scores, and another measured in an interval scale, such as the eye-hand developmental quotients (Champion, 1981). The calculated coefficient was $r_{(M)} = 0.13$, revealing that visual orientation scores at 40 weeks PCA were not correlated with eye-hand developmental quotients at 12 months corrected age (p=0.31). The scattergram in Figure 4 shows a positive tendency in the relationship between visual orientation scores at 40 weeks and eye-hand performance at 12 months, however, this relationship was not found to be statistically significant.

FIGURE 3

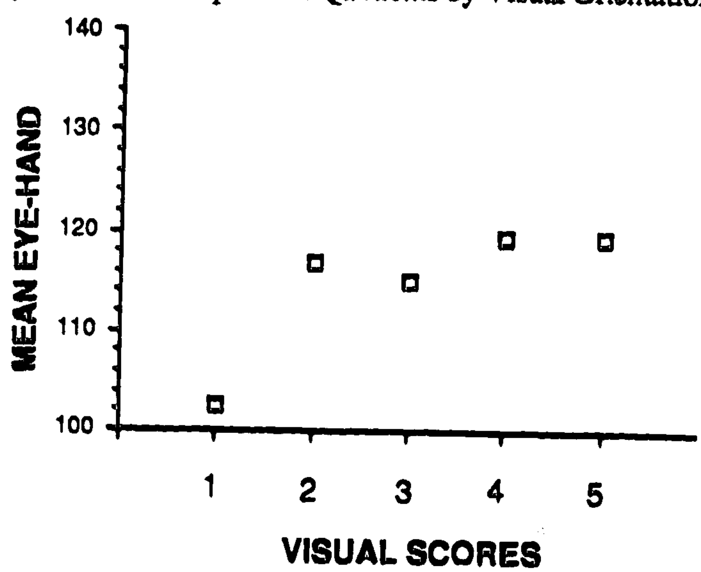
Eye-Hand Developmental Quotients According to Visual Orientation Categories



Error bars= 1 standard error of the mean

FIGURE 4

Mean Eye-Hand Developmental Quotients by Visual Orientation Scores



III. Difference Between Gestational Age Groups on Eye-Hand Performance at 12 months

In order to test whether the 2 gestational age groups (<32 weeks; 32-36 weeks) differ significantly on their eye-hand performance at 12 months corrected age, an unpaired t-test was conducted. The findings show that infants born between 32-36 weeks gestation had significantly higher ($p=0.0004$; $df=71$) eye-hand performance at 12 months corrected age than infants born at <32 weeks gestation. The descriptive results are reported in Table 7.

IV. Stepwise Multiple Regression Analysis for Eye-Hand Performance at 12 months

A stepwise multiple regression analysis was performed to determine which variable or combination of variables were associated with eye-hand performance at 12 months. In stepwise multiple regression the independent variable with the strongest association with the dependent variable is entered first, if it meets the entry requirement (probability of F-to-enter less than or equal to the default value of 0.05). Then, each of the remaining independent variables not in the equation is examined for entry. If the entry criterion is met, the second variable is selected based on the highest partial correlation with the dependent variable (Norusis, 1983). The process continues until there are no other variable that meet the entry criterion (Tabachnick & Fidell, 1983). The independent variables were: gestational age at birth, visual orientation scores (1, 2, 3, 4, 5), and neurological status (normal, suspicious, abnormal). The descriptive values for the analysis are shown on Table 8. Neurological status at 18 months corrected age was the most significant variable associated with eye-hand performance at 12 months corrected age ($p= 0.00$). It accounted for 32% of the variance in eye-hand developmental quotients. In the second step gestational age at birth was entered as significantly correlated with eye-hand performance at 12 months ($p= 0.05$), and it accounted for an extra 4% of the variance in the dependent variable (R^2[2nd Step]=

0.36). Visual orientation scores at 40 weeks PCA failed to contribute significantly to the equation after the entrance of the first two independent variables (p= 0.42).

TABLE 7

Eye-Hand Developmental Quotients According to Gestational Age Groups

CHARACTERISTIC	MEAN EYE-HAND QUOTIENT	t VALUE (unpaired)	p VALUE (2-tail)
GESTATIONAL AGE GROUP		-3.73	0.0004
<32 WEEKS (n= 34)	108.73 (SD: 21.47)		
32-36 WEEKS (n= 39)	122.79 (SD: 9.08)		

SD: Standard Deviation

TABLE 8

Stepwise Multiple Regression Analysis on Explanatory Variables for Eye-Hand Performance at 12 months (n = 73)

VARIABLE ENTERED	EXPLANATORY VARIABLE	R^2††	MULTIPLE R	F	pVALUE (2- tail)
STEP 1	NEUROLOGICAL STATUS	0.32	0.56	33.20	0.001
STEP 2	GESTATIONAL AGE	0.03	0.60	3.96†	0.05†

†= F test and level of significance referent to the independent variable before entering the equation.
R^2††= Multiple Correlation Squared (the total variance in eye-hand quotients accounted for by each of the explanatory variable before entering the equation).

CHARACTERISTICS OF THE NEUROLOGICALLY NORMAL GROUP OF PRETERM INFANTS

Because neurological outcome was found to be strongly correlated with eye-hand performance at 12 months the same statistical analyses were conducted using only those infants who were diagnosed as neurologically normal at 18 months corrected age (n=45). This procedure enabled the investigation of the possible impact that gestational age and visual orientation may have on eye-hand performance at 12 months, without the influence of poor neurological outcome (abnormal, suspicious).

The neurological outcome for the entire cohort of infants was described earlier in this chapter on Table 3 (p. 37). Of the 73 infants in the study sample 45 (61.64%) were assessed as being neurologically normal at 18 months corrected age. Of the 45 neurologically normal infants at 18 months corrected age, 18 (40%) were born at < 32 weeks PCA and 27 (60%) were born 32-36 weeks PCA. The frequencies of gender, gestational age at birth and birthweight for the 45 normal infants are described in Table 7.

The frequencies of the visual orientation scores for the 45 normals infants, as assessed with the Neurological Assessment of the Preterm and Fullterm Newborn Infant (Dubowitz & Dubowitz, 1981) at 40 weeks PCA, are illustrated in Figure 5. As can be seen the overall pattern of scores is the same as was found with the entire cohort. The visual orientation scores were classified into the two categories: "non-optimal" (scores 1 and 2; n=10), and "optimal" (scores 3, 4, and 5; n=35). Refer to the Methods section (p. 29) for the rationale for these criteria.

TABLE 9

Frequencies of Gender, Gestational Age, and Birthweight for the Neurologically Normal Infants, by Gestational Age Group

CHARACTERISTIC	GESTATIONAL AGE GROUP			
	<32 WEEKS (n=18)		32-36 WEEKS (n=27)	
GENDER				
MALE	10	(55.56%)	14	(51.85%)
FEMALE	8	(44.44%)	13	(48.15%)
GESTATIONAL AGE				
25-27 WEEKS	5	(27.78%)	_	
28-29 WEEKS	8	(44.44%)	_	
30-31 WEEKS	5	(27.78%)	_	
32-33 WEEKS	_		13	(48.15%)
34-36 WEEKS	_		14	(51.85%)
BIRTHWEIGHT				
< 750 gm	1	(5.56%)	_	
750-1000 gm	5	(27.78%)	_	
1001-1500 gm	8	(44.44%)	1	(3.70%)
1501-2500 gm	4	(22.22%)	24	(88.89%)
> 2500 gm	_		2	(7.41%)

INFERENTIAL ANALYSES

I. Comparison of G.A. groups on Visual Orientation at 40 weeks PCA

The two gestational age groups of neurologically normal infants were compared on their visual orientation scores at 40 weeks PCA by first performing a Chi-Square analysis as previously described. The observed frequencies of visual orientation did not significantly differ from the expected frequencies (p= 0.7144; with continuity correction applied). The findings are reported in Table 8 and Figure 6.

TABLE 10

Comparison of Gestational Age Groups by Visual Orientation Categories for the Neurologically Normal Infants (X^2= 0.13; p=0.714; df=1†)

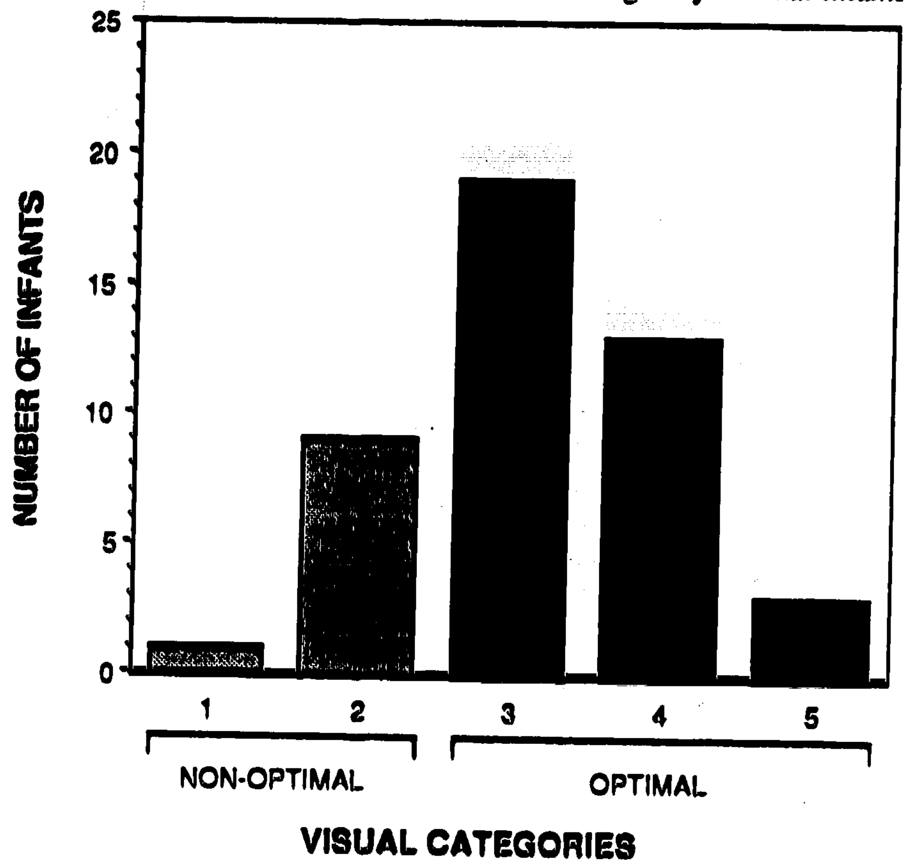
VISUAL ORIENTATION CATEGORIES	GESTATIONAL AGE GROUPS <32 WEEKS (n=18)		32-36WEEKS (n=27)	
OBSERVED FREQUENCIES				
OPTIMAL	13	(72.22%)	22	(81.48%)
NON-OPTIMAL	5	(27.78%)	5	(18.52%)
EXPECTED FREQUENCIES				
OPTIMAL	14	(77.78%)	21	(77.78%)
NON-OPTIMAL	4	(22.22%)	6	(22.22%)

†df= degrees of freedom

To compare the two gestational age groups of neurologically normal preterm infants (<32 weeks; 32-36 weeks) on the actual scores obtained on the visual orientation item (1, 2, 3, 4, or 5), a Mann-Whitney U test was conducted. No significant difference between the two gestational age groups on visual orientation scores was found (p=0.115; U=175). The results are reported in Table 11.

FIGURE 5

Frequency of Visual Orientation Scores for the Neurologically Normal Infants



Legend for Visual Orientation Scores:
1= The infant does not focus or follow stimulus
2= Stills; focus on stimulus; may follow 30° jerkily; does not find stimulus again spontaneously
3= Follows 30-60° horizontally; may lose stimulus but finds it again. Brief vertical glance
4= Follows with eyes and head horizontally and to some extent vertically with frowning
5= Sustained fixation; follows vertically, horizontally, and in circle.

FIGURE 6

Observed Frequencies of Visual Orientation at 40 weeks PCA According to Gestational Age for the Neurologically Normal Infants

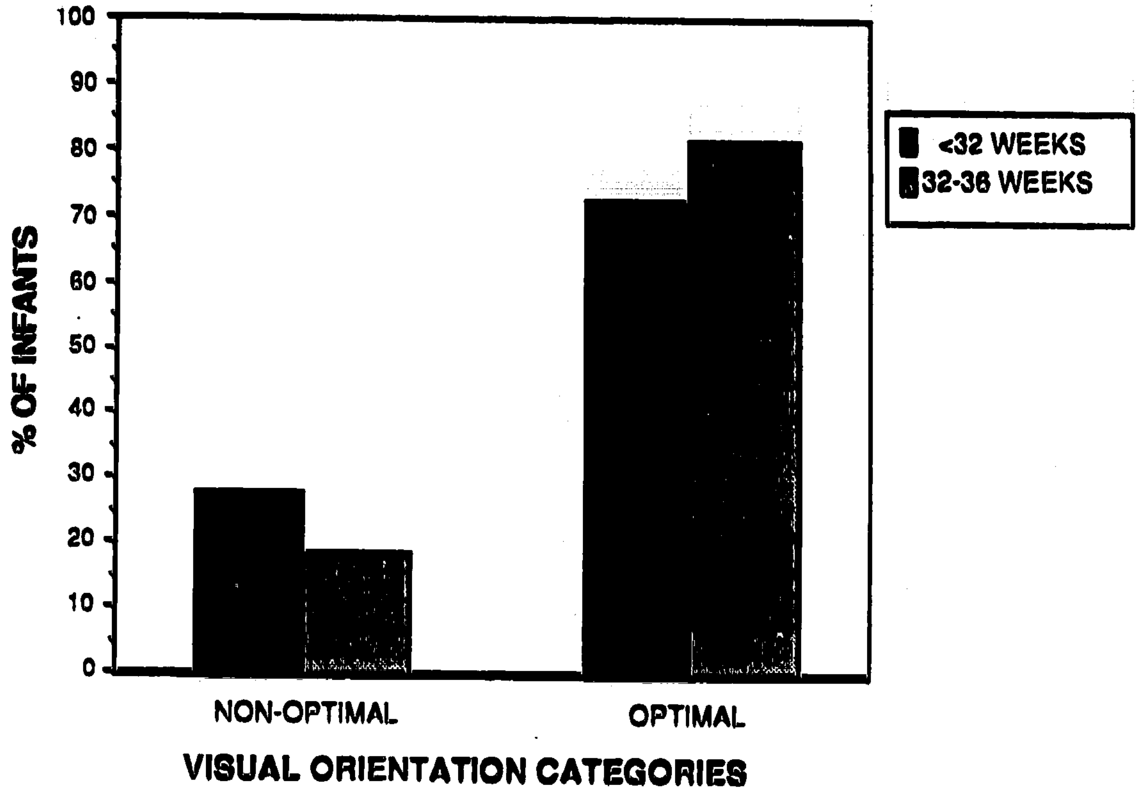


TABLE 11

Frequencies of Visual Orientation Scores According to Gestational Age Groups for the Neurologically Normal Infants (z=-1.58; p=0.115)

VISUAL SCORES	GESTATIONAL AGE GROUP			
	<32 WEEKS (n=18)		32-36 WEEKS (n=27)	
1	–		1	(3.70%)
2	5	(27.80%)	4	(14.80%)
3	10	(55.60%)	9	(33.30%)
4	2	(11.10%)	11	(40.70%)
5	1	(5.60%)	2	(7.40%)

II. Comparison of Optimal/Non-Optimal Visual Orientation Categories (40 weeks PCA) on Eye-Hand Performance at 12 months

Ten of the 45 neurologically normal infants (22.22%) had scores of 1 or 2 (non-optimal visual orientation), and 35 of the 45 normal infants (77.78%) had scores of 3, 4, or 5 (optimal visual orientation). See Figure 5. An unpaired t-test was conducted to compare the "optimal" infants with the "non-optimal" infants, on eye-hand performance at 12 months corrected age. The results revealed that infants who had "non-optimal" visual orientation at 40 weeks post-conception had significantly higher eye-hand quotients at 12 months corrected age than infants who had "optimal" visual orientation (p= 0.015; df=43). The results are reported in Figure 7 and Table 12.

TABLE 12

Eye-Hand Developmental Quotients According to Visual Orientation Categories for the Neurologically Normal Infants

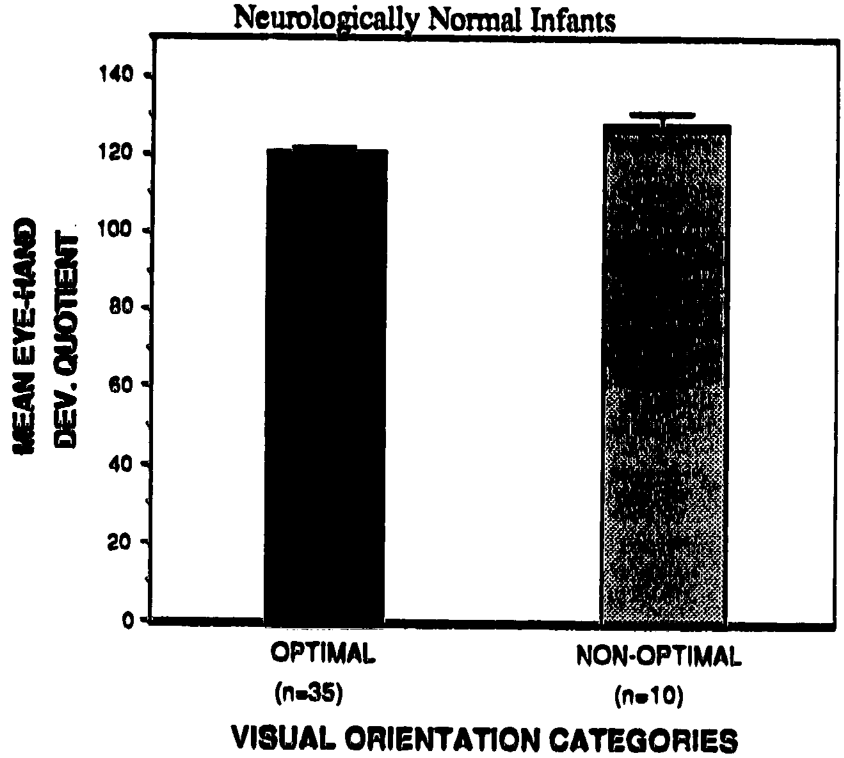
CHARACTERISTIC	MEAN EYE-HAND QUOTIENT	t VALUE (unpaired)	p VALUE (2-tail)
VISUAL ORIENTATION		2.53	0.015
OPTIMAL (n=35)	120.32		
	(SD: 8.24)		
NON-OPTIMAL (n=10)	127.96		
	(SD: 8.99)		

SD: Standard Deviation

Jaspen's M coefficient of multiserial correlation was calculated to compare the actual visual orientation scores at 40 weeks (1, 2, 3, 4, and 5) with eye-hand developmental quotients at 12 months corrected age, for the 45 normal infants. The calculated coefficient was r(M)= -0.28, revealing that visual orientation scores at 40 weeks PCA were negatively correlated with eye-hand developmental quotients at 12 months corrected age (p=0.06), although the strength of this association was poor. The scattergram in Figure 8 shows a negative tendency in the relationship between visual orientation scores at 40 weeks PCA and eye-hand performance at 12 months corrected age. This relationship approached significance levels (p= 0.06).

FIGURE 7

Eye-Hand Developmental Quotients According to Visual Orientation Categories for the Neurologically Normal Infants



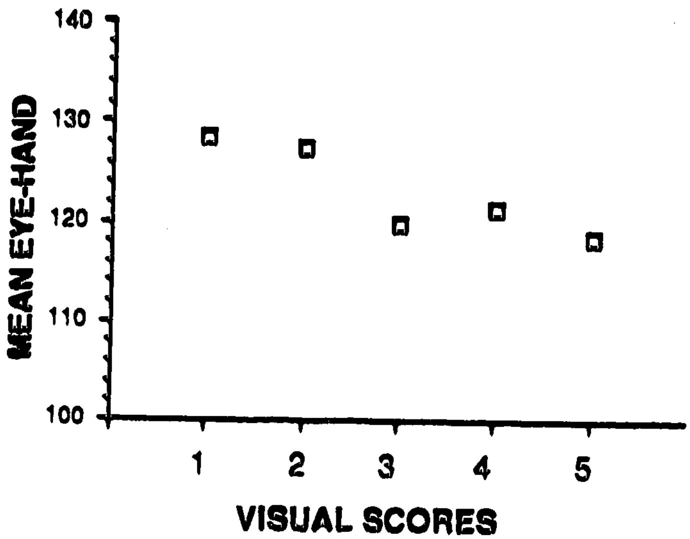
Error bars= 1 standard error of the mean

III. Difference Between Gestational Age Groups on Eye-Hand Performance at 12 months

With the group of neurologically normal infants an unpaired t-test was conducted to examine whether the two gestational age groups (<32 weeks; 32-36 weeks) differ on the eye-hand performance at 12 months corrected age. The findings fail to show a statistically significant difference between the two gestational age groups on the eye-hand developmental quotients for the neurologically normal group of infants ($p= 0.09$; $df=43$). The descriptive results are reported in Table 13.

FIGURE 8

Mean Eye-Hand Developmental Quotients by Visual Orientation Scores for the Neurologically Normal Infants



IV. <u>Stepwise Multiple Regression Analysis for Eye-Hand Performance at 12 months</u>

A stepwise multiple regression analysis was performed to determine which variable or combination of variables were associated with eye-hand performance at 12 months, for the normal group of infants. The independent variables were: gestational age at birth, and visual orientation scores (1, 2, 3, 4, 5). Neither of them reached significance. The descriptive values are shown on Table 14.

TABLE 13

Eye-Hand Developmental Quotients According to Gestational Age Groups for the Neurologically Normal Infants

CHARACTERISTIC VALUE	MEAN EYE-HAND QUOTIENT	t VALUE	p (2-tail)
GESTATIONAL AGE GROUPS		-.1.73	0.09
<32 WEEKS (n= 18)	119.27 (SD: 9.79)		
32-36 WEEKS (n=27)	123.85 (SD: 7.93)		

SD: Standard Deviation

TABLE 14

Stepwise Multiple Regression Analysis on Explanatory Variables for Eye-Hand Performance at 12 months for the Neurologically Normal Infants (n=45)

VARIABLE ENTERED	EXPLANATORY VARIABLE	$R^{2\dagger\dagger}$	MULTIPLE R	F	p VALUE (2-tail)
STEP 1	VISUAL ORIENTATION	0.07	0.28	3.64	0.06
STEP 2	GESTATIONAL AGE	0.04	0.35	2.32†	0.13†

†= F test and level of significance referent to the independent variable before entering the equation.
$R^{2\dagger\dagger}$= Multiple Correlation Squared (the total variance in eye-hand quotients accounted for by each of the explanatory variables before entering the equation).

CHAPTER V

DISCUSSION

This study had three major objectives. First, it aimed to evaluate the impact of gestational age at birth and the subsequent extrauterine environment on visual orientation at 40 weeks post-conceptional age (PCA). Second, it examined the relationships between preterm infants' visual orientation at 40 weeks PCA with eye-hand performance at 12 months corrected age, and between gestational age at birth with eye-hand performance at one year of age. Finally, it studied the association of gestational age at birth, visual orientation at 40 weeks PCA, and neurological status at 18 months corrected age with eye-hand performance at 12 months corrected age. These objectives were examined in two groups of infants: 1) the entire cohort of preterm infants (n=73), and 2) a sub-group of preterm infants who were diagnosed as neurologically normal at 18 months corrected age (n=45).

The results of this study demonstrated that the frequency of poor neurological outcome is higher among preterm infants born at younger gestational ages than among infants born at older gestational ages. Thus, as presented in Table 3 (p. 37), 47% of the infants born at <32 weeks gestation had a neurologically suspicious or abnormal outcome, compared with 31% of infants born between 32-36 weeks gestational age. Because of the strong association between gestational age at birth and neurological outcome, it is difficult to assess the impact of preterm birth on infants' visual orientation or eye-hand performance without taking into account neurological outcome.

When considering the entire cohort (N= 73), infants born at <32 weeks gestation showed significantly poorer visual orientation and lower eye-hand quotients than infants born 32-36 weeks gestation. When the neurologically normal preterm infants (N=45) were considered as a separate group, these results were not confirmed.

Rather, the two gestational age groups of normal preterm infants (<32 weeks gestation; 32-36 weeks gestation) did not differ significantly on either visual orientation at term or eye-hand performance at 12 months corrected age. Consequently, it is possible to conclude that the lower performance demonstrated by the preterm infants born at younger gestational ages may be more strongly attributed to their poor neurological status than to early birth itself. Thus, in an attempt to eliminate the effect of neurological status, the analyses were performed with the group of neurologically normal preterm infants (n= 45). The following discussion addresses only this group.

When considering the neurologically normal group of infants, the results revealed three major findings: 1) gestational age at birth did not impact on preterm infants' visual orientation at 40 weeks PCA; 2) gestational age at birth did not impact on eye-hand performance at 12 months corrected age; and 3) visual orientation at 40 weeks PCA was negatively correlated with eye-hand performance at 12 months corrected age.

This study failed to show a relationship between gestational age at birth and visual orientation at 40 weeks PCA. This particular finding is in disagreement with those studies that found the prolonged extrauterine environment experienced by young preterm infants to have a negative impact on early visual processing (Ferrari et al., 1983; Morante et al., 1982). It is also in disagreement with the investigators who contend that extrauterine experience has a positive impact on early visual processing (Baraldi et al., 1981; Kopp et al., 1975). Rather, this finding suggests that early visual orientation is not affected by gestational age at birth, among neurologically normal preterm infants and consequently, prolonged extrauterine experience neither enhances nor retards preterm infants' visual orientation at term. This finding is in agreement with that reported by Parmelee (1975). He found no consistent evidence to support the suggestion that the development of preterm infants may be either advanced or retarded by prolonged exposure to extrauterine environment. According to Allen & Capute (1986b) and Parmelee (1975), prolonged extrauterine experience does not have a measurable effect on visual responses such as preferential looking, visually evoked potentials, habituation to light, and optokinetic nystagmus. The present study suggests that prolonged extrauterine experience may also not have a measurable effect on visual orientation at 40 weeks PCA among neurologically normal preterm infants.

The second major finding from this study revealed that gestational age at birth is not significantly related to later eye-hand performance among normal preterm children. In fact, in the current study all preterm infants with normal neurological status performed within expected age ranges on the eye-hand subscale of the Griffiths assessment. This finding supports the theory of development of Gesell (1933) and Saint-Anne Dargassies (1966) that development is biologically driven, regardless of the environmental experience. According to this theory infants should have similar developmental outcomes, when examined at the same age post conception, regardless of their gestational age at birth. However, contrary to both this theory and the results reported in this study, a number of other researchers have shown poorer performance among preterm infants, especially in the area of fine motor development, and have attributed their findings to the difference in gestational age. Piper et al. (in press) observed both gross and fine motor performance of two gestational age groups of preterm infants at eight and 12 months of age and found that infants born at younger gestational ages showed poorer fine motor performance than infants born at older gestational ages.

Other investigators have reported similar delays in fine motor development when comparing preterm with full-term infants. Field et al. (1981) followed a group of preterm infants with respiratory distress syndrome. At 8 months corrected age they reported poorer performance on items requiring fine-motor abilities by the preterm group when compared with full-term and post-term infants. Ross (1985) and Forslund & Bjerre (1985) reported similar results. According to Ross (1985), at 12 months corrected age the preterm group was less likely to succeed on items involving eye-hand coordination, imitation, and vocalization. Forslund & Bjerre (1985) also observed a delayed performance on fine motor development among preterm infants, when compared with full-terms, at 18 months of age. Two major differences between these investigations and the present study may serve to explain the discrepancies in the reported results. First, while none of them had controlled for neurological disorders among the preterm infants, this present study examined a group of neurologically normal infants separate from the entire cohort. In fact, neurological disorders may have accounted for the delayed performance on fine motor development among preterm infants that was observed by those earlier investigators. The second difference relates to the fact that the studies by Field et al. (1981), Forslund & Bjerre (1985) and Ross (1985) compared the development of preterm with that of full-term infants, while the present study examined two groups of preterm infants born at different gestational ages. Some investigators argue that preterm infants are a unique group with specific patterns of development and, therefore, their performance should not be compared with that of full-term infants (Aylward, 1981; Paludetto et al., 1984; Sigman & Beckwith, 1980).

Besides being in disagreement with studies that compared preterm with full-term infants, the findings from this study also differ from those of studies that compared two different gestational age groups of preterm infants. Piper et al. (in press) in a study that assessed many of the same normal infants reported here, examined the gross and fine motor performance of two groups of preterm infants born at different gestational ages. Even when correction for prematurity was performed, infants born at younger gestational ages showed a significantly poorer fine motor performance than infants born at older gestational ages. In the present study, while the performance of the two gestational age groups was not significantly different, infants born at <32 weeks PCA consistently demonstrated lower eye-hand quotients than infants born between 32-36 weeks PCA. The discrepancies in the results from the two studies may be attributed to the small sample size. Because the results here approached significance, it is possible that a larger sample size might have shown a significant difference between the two gestational age groups on the eye-hand performance at 12 months corrected age, or might have served to reassure the finding reported in the present study.

The third major finding from this study suggested that the visual orientation of neurologically normal preterm infants at 40 weeks PCA was negatively related to eye-hand performance at 12 months corrected age. Although all neurologically normal preterm infants performed within the normal range in the eye-hand assessment at 12 months corrected age, those who had "optimal" visual orientation at 40 weeks PCA obtained significantly lower eye-hand quotients at 12 months than the preterm infants who had "non-optimal" visual orientation. When examining the correlation between the actual visual orientation scores (e.g. 1, 2, 3, 4, 5) and later eye-hand quotients, the relationship was found to be negative but it was neither strong ($r_M = -0.28$) nor statistically significant ($p = 0.06$). These two statistical analyses examined the data from two different perspectives. The correlation analysis correlated the visual orientation <u>scores</u> obtained by the preterm infants at 40 weeks PCA with their eye-hand quotients at 12 months corrected age. The t-test analysis used the visual orientation <u>categories</u> and tested whether the group of infants who had an "optimal" visual orientation at 40 weeks PCA differed from the group that had a "non-optimal" visual orientation, on their eye-hand quotients at 12 months. The criteria used to define the two visual orientation categories may explain the difference found between analyses. "Optimal" visual orientation included the scores of 3, 4 and 5. The score of 3 was the mode response among the preterm infants (Figures 1 and 5); consequently, it seemed appropriate to consider the visual orientation evidenced by the majority of subjects as being "optimal". The scores of 1 and 2 were then considered as being "non-optimal" responses. Although we cannot ignore that the eye-hand performance of the normal infants who had an "optimal" response was significantly different from the eye-hand performance of those who had a "non-optimal" response, the criterion used to allocate the infants into the "optimal" and "non-optimal" categories was somewhat arbitrary and as such may not have been the best way of analyzing the visual orientation scores. It might be concluded that the correlation analysis, using actual scores rather than categories of function, produced more meaningful results regarding the early visual orientation and later eye-hand performance of normal preterm infants.

The correlation between early visual orientation scores and later eye-hand quotients did approach significance and, although it was not strong, it did show a trend towards a negative relationship between these two variables. This is an unexpected finding. There are two methodological issues that may have influenced this finding: 1) the assessment tools used to measure both visual orientation at 40 weeks PCA and eye-hand performance at 12 months of age may not be valid measures of these two functions; and 2) during the 12 month period between the assessments of visual orientation and eye-hand performance, the infants were not monitored on possible environmental stimulation that may have contributed to the relationship found between these variables.

In the present study, the assessment tool used to measure eye-hand performance at 12 months corrected age was not a specific measure of visual motor behavior. Rather, at 12 months, the eye-hand subscale from the Griffiths Mental Developmental Scale basically measures whether the infant can hold a pencil and use it on paper (see Table 15). Such items do not specifically require infants' visual attentiveness during the motor behavior. Furthermore, this scale has a pass/fail scoring criteria and does not evaluate the quality of the response given by the infant. It may be as possible for a visually impaired child to pass items such as "can hold a pencil" and "use it on paper" as it is for a child with normal visual abilities. In this case, a more specific assessment may have provided more valid information regarding the relationship between visual and fine motor abilities. The items from the fine motor scale of the Peabody Developmental Motor Scales (Folio & Fewell, 1983) are examples of tasks involving visual motor behavior. Such items require the child to open a box and remove candy pellets, turn pages from a book, build a tower with four cubes, etc. These items appear to require greater integration of visual motor skills. In addition the Peabody Developmental Fine Motor Scales have a larger number of items involving visual motor skills, and this may give more valid index of fine motor function. Consequently, the fine motor scale of the Peabody Developmental Motor Scales may be a more accurate measure of infants' eye-hand performance than the eye-hand subscale from the Griffiths Mental Developmental Scale, as it focuses more on infants' visual motor abilities.

In addition to the limitations addressed in relation to the measure of eye-hand performance, the measure of visual orientation itself is subject to criticism. This study used only one item from a multiple item assessment tool and compared the response from this item with outcome at 12 months. It is possible and likely that the visual orientation item from the Neurological Assessment of the Preterm and Full-term Newborn Infant (Dubowitz & Dubowitz, 1981) was not meant to stand by itself as an early indication of later eye-hand performance of preterm infants. Taken by itself, the visual orientation item has a subjective scoring criteria. It relies on the examiner's judgement to decide whether the infant followed 30° jerkily (score of 2) or followed 30-60° horizontally (score of 3). While the reliability of this item has not been reported, the authors of the original neurological assessment noted that the entire tool has shown good inter-observer coefficients (Dubowitz & Dubowitz, 1981). It is known that the reliability of an assessment tool does not guarantee the same stability of its separate individual items (Brazelton, 1984).

Investigators have used visual orientation responses to document the development of visual function among preterm (Dubowitz, 1979) and full-term infants (Brazelton, 1984), up to 40 weeks PCA. The visual orientation of preterm infants has also been compared with the visual orientation of full-term infants, both at 40 weeks PCA (Ferrari et al., 1983; Forslund & Bjerre, 1983). Most investigators argue that visual orientation responses in newborn infants are good indicators of early visual functioning as well as of neurological maturity (Brazelton, 1966; Brazelton, 1984; Dubowitz, 1979). These studies differ from the present study in terms of methodology

TABLE 15

Items from the Eye and Hand Subscale of the Griffiths Mental Developmental Scale

MONTHS OF AGE	ITEM DESCRIPTION
10	-Plays pulling ring or toy by string
	Throws objects.
11	-Thumb opposition complete;
	Can point with index finger.
12	-Interested in motor-car;
	Can hold pencil as if to mark on paper;
	Uses pencil on paper a little.
13	-Likes holding little toys;
	Preference for one hand.
14	-Plays rolling ball;
	Can hold 4 cubes in hands at once.

employed. While the earlier studies specifically examined the visual orientation responses of infants as a single item assessment, the present study extracted one item from a general neurological procedure. It is possible that the items of the neurological examination which were tested prior to the visual orientation item may have interfered with the visual response given by the infant. By using one item from an entire battery of items, to measure infants' visual orientation at 40 weeks PCA, this study may not have validly assessed the actual visual orientation status of the preterm infants, thereby, accounting for the negative relationship between early visual orientation and later eye-hand performance. While earlier studies have used this visual orientation item to describe the visual functioning of preterm and full-term infants (Brazelton, 1966; Dubowitz, 1979), the visual orientation as tested here may only be a good indicator of early function rather than a predictor of later more complex visual motor skills such as those required in eye-hand coordination. Future studies employing more appropriate measures of visual orientation and eye-hand performance should be conducted in order to better evaluate the relationship between these variables.

The fact that the two measurements were performed 12 months apart and that the infants were not monitored for possible stimulation (environment, treatment), may also have contributed to the negative relationship between infants' visual orientation (assessed at 40 weeks PCA) and eye-hand performance (assessed at 12 months corrected age). It is possible that parents of the infants who received lower scores on visual orientation may have become aware of their children's poor visual abilities and provided appropriate play activities which served to enhance their eye-hand or fine motor skills. Consequently, environmental stimulation, which was not held as a constant variable, might have influenced the findings from this study. This explanation is in agreement with that provided by Sigman & Beckwith (1980). Their study examined the correlation between preterm and full-term infants' visual fixation at term with developmental outcome at two years of age, as measured by the Bayley Mental Scale. In the preterm group there was a negative relationship between amount of early visual fixation and the developmental outcome recorded at two years. According to the authors, one factor that may have accounted for the negative relationship reported was the two year period between the two measures. Indeed, prospective studies that look for early predictors of later developmental outcome should account for the possible environmental stimulation that infants receive from their caregivers, as it might influence developmental outcome.

The negative relationship found between early visual orientation and later eye-hand performance was attributed to two methodological limitations of this study. Although it is possible that environmental stimulation might have interfered with later eye-hand performance more strongly than early visual orientation, it is also likely that the negative relationship is explained by the inaccuracy of the assessment tools used. Indeed, neither of these two limitations can fully account for the negative relationship reported in this study. Rather, it is probable that these two methodological issues may have combined together to produce this unexpected finding. Future investigation is needed to describe the actual relationship between early visual orientation and later eye-hand performance.

In summary, in agreement with other investigations, the findings from this study indicated that poor neurological outcome interferes with preterm infants' developmental outcome at a further point in time. Furthermore, gestational age at birth did not impact on early visual orientation or on later eye-hand performance, among neurologically normal preterm infants. Finally, the study reported a negative relationship between visual orientation at 40 weeks PCA and eye-hand performance at 12 months corrected age. This final finding is partially explained by methodological flaws. Further research in this area is recommended.

CHAPTER V

SUMMARY AND CONCLUSIONS

The findings of this study suggested that neurological outcome strongly impacts on preterm infants' developmental performance. Indeed, the results of the analyses performed with the entire cohort of infants differed considerably from the results of the analyses performed with only the neurologically normal preterm infants. Consequently, when examining the impact of preterm birth, per se, on infants' developmental performance, neurological outcome should be taken into consideration.

No significant relationship was found between gestational age at birth and visual orientation at 40 weeks PCA. This finding supports the premise that the amount of extrauterine experience neither enhances nor retards the development of visual skills such as the ability to focus on and follow a visual stimulus. The results also fail to demonstrate a significant relationship between gestational age at birth and later eye-hand performance. Furthermore, this study reported a negative relationship between early visual orientation and later eye-hand performance. This negative relationship was partially attributed to the inadequate measures of early visual orientation and later eye-hand performance of preterm infants. Besides using more accurate instruments it is suggested that future studies also monitor the environment that infants experience, in an attempt to control for the stimulation that infants may have received during the 12 month period between the first and second evaluations.

Significance of the Study

Studies examining the development of preterm infants have reported some delays in fine-motor development, particularly in those abilities involving visual-motor functions (Klein et al., 1985; Piper et al., in press; Ungerer & Sigman, 1983). The current study aimed to investigate possible predictors of later eye-hand performance in preterm infants. Specifically, the findings from this study provided significant information regarding the impact of gestational age at birth on visual orientation at 40 weeks PCA, and on the association between visual orientation at 40 weeks PCA with eye-hand performance at 12 months corrected age. These findings have relevance for therapists who work in early intervention programs with preterm infants, since they address factors that may or may not influence later development.

The findings in this study suggest that young gestational age at birth and the subsequent extrauterine environment experience neither retard nor enhance visual orienting or eye-hand performance of neurologically normal preterm infants. According to this finding, for neurologically normal preterm infants, gestational age at birth does not impact on either their ability to focus on a stimulus and to track it in different directions, at 40 weeks PCA, or on their eye-hand performance at 12 months corrected age. It implies that prolonged extrauterine environment, which provided visual experience as well as motor activity to normal young preterm infants is not harmful to their performance, when they were compared to their older counterparters. Also, the findings from this study do not provide evidence to support the premise that early experience enhances normal young preterm infants' visual orientation or eye-hand performance. If these data are replicated by future research, the therapeutic practice of environmental intervention for neurologically normal preterm infants must be strongly questioned. Also, intervention programs aiming to improve fine motor performance among normal young preterm infants should be reviewed.

When neurological outcome was not taken into account, the findings of this study showed that younger preterm infants had poorer visual orientation and poorer eye-hand performance than the older group. As most early intervention programs are directed towards the neurologically suspicious and abnormal infants, the role of the therapists' intervention with this group of infants should be further investigated. Indeed, therapists have been evaluating the efficacy of early intervention programs in an attempt to justify their practice (Anderson, 1986; Case-Smith, 1988; Leib et al., 1980). Leib et al. (1980) and Case-Smith (1988) contend that early intervention methods involving sensory stimulation produce improved developmental outcomes for high-risk preterm infants. The results of these studies suggest that there may well be a role for therapists working with infants who are likely to have a suspicious or abnormal neurological outcome. Consequently, neurological outcome may be used as an indicator for defining the group of preterm infants who should receive early intervention programs.

A common limitation among the studies that examine the developmental performance of preterm infants refers to the fact that most assessment tools are normed on the performance of full-term infants. Consequently, the preterm population may be mistakenly described as having either enhanced or retarded performance when measured with these assessment tools. The present study reinforces the need for the development of assessment tools normed among preterm infants. It is critical that valid measures be developed in order to properly document the development of preterm infants. Only by using measurement tools which appropriately measure the developmental functioning of preterm infants, will it be possible to study the true relationship between the variables considered in the present study.

Future Directions

The results of this study reveal that neurological outcome is strongly associated with developmental performance of preterm infants. In order to study the impact of preterm birth on later developmental outcome, it is important to distinguish preterm birth from the medical complications associated with young gestational age at birth. As such, this study suggests that future investigators consider examining the development of neurologically normal preterm infants as one group and the neurologically suspicious and abnormals as a separate group. This study demonstrates that neurologically normal preterm infants born within two different gestational age groups did not differ significantly on either visual orientation at birth or on later eye-hand performance. Further investigation is required to determine how infants born at varying gestational ages are affected on their fine-motor development. It is also recommended that future studies that prospectively examine the impact of preterm birth on infants' developmental outcome consider monitoring the environment that the infant experiences. Finally, this study stresses the need for the development of assessment tools which have been normed on preterm infants, rather than full-terms.

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APPENDICES

APPENDIX A

Informed Consent Form†
(Preterm Infants)

I have been told that the objective of this study is to evaluate the effect of premature birth on early motor development. I have been informed that information will be taken from my child's birth and hospital records and that my child's motor development will be evaluated several times during his hospital stay. In addition, I understand that my child's motor development will be evaluated six times during his first year of life and once again during his second year of life. All assessments will be observational in nature and will not involve any equipment or invasive techniques.

I have been assured that no information which could influence my decision to allow my child to participate has been withheld from me. There have been no restrictions on the questions I have wanted to ask to better understand the nature of the study. I have also been assured that my decision to give or withhold my consent will in no way affect the other treatments or services my child receives.

I am aware that I am free to withdraw my consent and to discontinue my child's participation in the research project at any time.

NAME:____________________________
(please print)

DATE:____________________________

SIGNATURE: _______________________

WITNESS:_________________________

† From the study entitled: "Impact of preterm birth on the neuromotor development of the premature infant" by Dr. M.C. Piper & Dr. P. Byrne

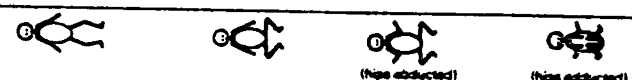
APPENDIX B

The Neurological Assessment of The Preterm and Fullterm Newborn Infant

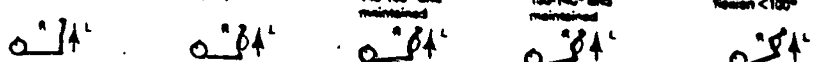
NAME		D.O.B./TIME	WEIGHT	E.D.D. L.N.M.P.	E.D.D. U/snd.
HOSP.	NO.	DATE OF EXAM	HEIGHT		
RACE	SEX	AGE	HEAD CIRC.	GESTATIONAL ASSESSMENT	SCORE WEEKS

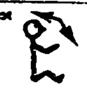
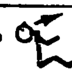
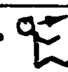
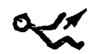
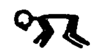
STATES
1. Deep sleep, no movement, regular breathing.
2. Light sleep, eyes shut, some movement.
3. Dozing, eyes opening and closing.
4. Awake, eyes open, minimal movement.
5. Wide awake, vigorous movement.
6. Crying.

						STATE	COMMENT	ASYMMETRY
HABITUATION (≤state 3)								
LIGHT Repetitive flashlight stimuli (10) with 5 sec. gap. Shutdown = 2 consecutive negative responses	No response	A. Blink response to first stimulus only. B. Tonic blink response. C. Variable response.	A. Shutdown of movement but blink persists 2-5 stimuli. B. Complete shutdown 2-5 stimuli.	A. Shutdown of movement but blink persists 6-10 stimuli. B. Complete shutdown 6-10 stimuli.	A. Equal response to 10 stimuli. B. Infant comes to fully alert state. C. Startles + major responses throughout.			
RATTLE Repetitive stimuli (10) with 5 sec. gap.	No response	A. Slight movement to first stimulus. B. Variable response.	Startle or movement 2-5 stimuli, then shutdown	Startle or movement 6-10 stimuli, then shutdown	A. B. C. Grading as above			
MOVEMENT & TONE	Undress infant							
POSTURE (At rest — predominant)			(hips abducted)	(hips adducted)	Abnormal postures: A. Opisthotonus. B. Unusual leg extension. C. Asymm. tonic neck reflex			
ARM RECOIL Infant supine. Take both hands, extend parallel to the body; hold approx. 2 secs. and release.	No flexion within 5 sec. R L	Partial flexion at elbow >100° within 4-5 sec. R L	Arms flex at elbow to <100° within 2-3 sec. R L	Sudden jerky flexion at elbow immediately after release to <60° R L	Difficult to extend; arm snaps back forcefully			
ARM TRACTION Infant supine; head midline; grasp wrist, slowly pull arm to vertical. Angle of arm scored and resistance noted at moment infant is initially lifted off and watched until shoulder off mattress. Do other arm.	Arm remains fully extended R L	Weak flexion maintained only momentarily R L	Arm flexed at elbow to 140° and maintained 5 sec. R L	Arm flexed at approx. 100° and maintained R L	Strong flexion of arm <100° and maintained R L			
LEG RECOIL First flex hips for 5 secs, then extend both legs of infant by traction on ankles; hold down on the bed for 2 secs. and release.	No flexion within 5 sec. R L	Incomplete flexion of hips within 5 sec. R L	Complete flexion within 5 sec. R L	Instantaneous complete flexion R L	Legs cannot be extended; snap back forcefully R L			
LEG TRACTION Infant supine. Grasp leg near ankle and slowly pull toward vertical until buttocks 1-2" off. Note resistance at knee and score angle. Do other leg.	No flexion R L	Partial flexion, rapidly lost R L	Knee flexion 140-160° and maintained R L	Knee flexion 100-140° and maintained R L	Strong resistance; flexion <100° R L			
POPLITEAL ANGLE Infant supine. Approximate knee and thigh to abdomen; extend leg by gentle pressure with index finger behind ankle.	180-160° R L	150-140° R L	130-120° R L	110-90° R L	<90° R L			








HEAD CONTROL (post. neck m.) Grasp infant by shoulders and raise to sitting position; allow head to fall forward; wait 30 sec.	No attempt to raise head 	Unsuccessful attempt to raise head upright 	Head raised smoothly to upright in 30 sec. but not maintained. 	Head raised smoothly to upright in 30 sec. and maintained 	Head cannot be flexed forward 			
HEAD CONTROL (ant. neck m.) Allow head to fall backward as you hold shoulders; wait 30 secs.	Grading as above 	Grading as above 	Grading as above 	Grading as above 				
HEAD LAG * Pull infant toward sitting posture by traction on both wrists. Also note arm flexion.								
VENTRAL SUSPENSION * Hold infant in ventral suspension; observe curvature of back, flexion of limbs and relation of head to trunk.								
HEAD RAISING IN PRONE POSITION Infant in prone position with head in midline.	No response	Rolls head to one side	Weak effort to raise head and turns raised head to one side	Infant lifts head, nose and chin off	Strong prolonged head lifting			
ARM RELEASE IN PRONE POSITION Head in midline. Infant in prone position; arms extended alongside body with palms up.	No effort	Some effort and wriggling	Flexion effort but neither wrist brought to nipple level	One or both wrists brought at least to nipple level without excessive body movement	Strong body movement with both wrists brought to face, or 'press-ups'			
SPONTANEOUS BODY MOVEMENT during examination (supine). If no spont. movement try to induce by cutaneous stimulation.	None or minimal Induced	A. Sluggish. B. Random, incoordinated. C. Mainly stretching.	Smooth movements alternating with random, stretching, athetoid or jerky	Smooth alternating movements of arms and legs with medium speed and intensity	Mainly: A. Jerky movement. B. Athetoid movement. C. Other abnormal movement.		1 2	
TREMORS Mark: Fast (>6/sec.) or Slow (<6/sec.)	No tremor	Tremors only in state 5-6	Tremors only in sleep or after Moro and startles	Some tremors in state 4	Tremulousness in all states			
STARTLES	No startles	Startles to sudden noise, Moro, bang on table only	Occasional spontaneous startle	2-5 spontaneous startles	6+ spontaneous startles			
ABNORMAL MOVEMENT OR POSTURE	No abnormal movement	A. Hands clenched but open intermittently. B. Hands do not open with Moro.	A. Some mouthing movement. B. Intermittent adducted thumb	A. Persistently adducted thumb. B. Hands clenched all the time.	A. Continuous mouthing movement. B. Convulsive movements.			

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THE IMPACT OF PRETERM BIRTH ON VISUAL ORIENTATION AT TERM AND EYE-HAND PERFORMANCE AT 12 MONTHS

BY

MARISA COTTA MANCINI

A THESIS

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research for acceptance, a thesis entitled "**IMPACT OF PRETERM BIRTH ON VISUAL ORIENTATION AT TERM AND EYE-HAND PERFORMANCE AT 12 MONTHS**" submitted by **Marisa Cotta Mancini** in partial fulfillment of the requirements for the degree of **Master of Science.**

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ABSTRACT

Seventy-three preterm infants were allocated to one of two groups according to their gestational age at birth (<32 weeks; 32-36 weeks). Because of the strong association between neurological outcome and developmental performance, forty-five neurologically normal preterm infants were identified at eighteen months of age and examined separately from the rest of the infants. The visual orientation of all infants was measured at forty weeks post-conception and their eye-hand performance was assessed at twelve months corrected age.

At term, the two gestational age groups of neurologically normal preterm infants did not differ significantly in terms of visual orientation responses. This study also failed to show a significant relationship between gestational age at birth and later eye-hand performance, in normal preterm infants. Furthermore, the visual orientation responses demonstrated by the normal preterm infants, at term, was found to be negatively associated with their eye-hand performance at twelve months corrected age. The extrauterine environment experienced by normal preterm infants neither enhanced nor retarded their visual orientation abilities at term, or their eye-hand performance at twelve months of age.

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CHAPTER I

INTRODUCTION

Prior to 1940, infants born prematurely received virtually no medical treatment; consequently, seventy percent of preterm infants died shortly after birth (Minde, 1984). With the advent of Neonatal Intensive Care Units (NICU), the life expectancy of very young preterm infants has increased significantly; the neonatal mortality rate in the United States has declined from 23 to 10 deaths per one thousand births. Currently, infants born as young as twenty-four weeks gestation and weighing less than 8 hundred grams are surviving (Allen & Capute, 1986; Kitchen et al., 1987).

Young gestational age at birth is often associated with poor neurological outcome (Pettett, 1986). Infants who are born too soon are more likely to have peri and postnatal medical complications than infants born at older gestational ages. These medical complications associated with young gestational age at birth threaten the optimal neurological development and may have a direct impact on later outcome (Pelletier & Palmeri, 1985; Ramm, 1988).

Preterm infants are known to be at risk for a number of minor developmental disorders including perceptual problems, delayed fine-motor performance, learning disabilities, and major disabilities such as cerebral palsy (Campbell & Wilhelm, 1985; Mulligan et al., 1980). They are also known to be at increased risk for vision-threatening conditions (Fledelius, 1976). One percent of preterm infants have some form of visual disablement. The most common ophthalmological problem among preterm infants is retinopathy of prematurity, however, the incidence of this problem has declined substantially with the control of oxygen therapy. Other visual impairments that can be found in preterm infants are reduced visual acuity, myopia, and strabismus (van-Holf van Duin & Mohn, 1984).

The visual system of preterm infants has been widely studied since its assessment is often used as a predictor of neurobehavioral development. Although the visual system is the last of the sensory systems to attain full maturity, many of its functions are used to assess neonates' behavioral responses at birth. Several investigators agree that the capacity of a neonate to fix, follow and alert to a visual stimulus provides information about the integrity of the visual pathway and may predict later intellectual performance (Brazelton et al., 1966; Dubowitz et al., 1980; Hack et al., 1981; Miranda et al., 1977; Placzek et al., 1985).

The role the extrauterine environment plays in the development of the preterm infant's sensory systems in general, and in the late maturing systems such as the visual system in particular, is still controversial. When the objective is to investigate potential factors that may alter developmental outcome it is important to first study the development of an optimal group of preterm infants. This study examined the impact of preterm birth on visual orientation at 40 weeks post-conception and on eye-hand performance at 12 months corrected age. In an attempt to separate the impact preterm birth may have on these factors from the influence associated with poor neurological outcome, infants neurological status were determined at 18 months. The group of preterm infants with normal neurological outcome at 18 months corrected age was then examined separately from the infants classified as neurologically suspicious and abnormal. Once neurological disorders have been controlled it allows meaningful examination of the impact of extrauterine experience on normal preterm infants' developmental outcome.

Relevance of the Study

While the advent of neonatal intensive care units has increased the life expectancy of very young preterm infants, there is still controversy as to what impact the artificial extrauterine environment has on the development of the central nervous system. Some investigators contend that the extrauterine environment has a positive effect and consequently, several aspects of preterm infants' development such as visual abilities are enhanced by this experience (Baraldi et al., 1981; Kopp et al., 1975; Palmer et al., 1982). Other investigators argue that the immaturity of many structures is negatively influenced by preterm birth, resulting in poor performance by this group of infants (Ferrari et al., 1983; Morante et al., 1982). In an attempt to add clarification to this conflict the present prospective study investigated the impact of preterm birth and the subsequent extrauterine experience on infants' ability to interact with the environment by means of early visual orientation and later eye-hand performance.

The integrity of both the sensory and the motor systems is extremely important for the child's interaction with the environment and the development of mature and specific abilities. Eye-hand coordination is one essential ability for the child's exploration of objects (Hofsten, 1982). Examining the impact of preterm birth on the acquisition of this visually directed fine-motor ability will provide important information as to the developmental outcome of fine-motor skills in preterm infants.

The study of early indicators of developmental outcome has become a major concern for pediatric therapists since these indicators give us information necessary to define which infants should be provided with therapy services. The present study intends to determine whether the visual orientation of preterm infants at 40 weeks post conceptional age and the gestational age at birth are indicators of eye-hand performance at 12 months corrected age. The findings from this study may provide useful information for early intervention programs directed towards improving the fine-motor developmental outcomes of infants born prematurely. Preterm infants are known to exhibit developmental delays in visual-motor skills (Holmes et al., 1988). If either gestational age at birth or visual orientation at 40 weeks post-conception are related to eye-hand performance at 12 months corrected age, they could be used for the early identification of children who are at risk for fine-motor disorders. Once such children were identified, early intervention programs could address the issue of enhancing development in this area.

Objectives

A) General Objective

The overall objective of this study is to evaluate the impact of preterm birth and the subsequent extrauterine environment experience on visual orientation at 40 weeks post-conceptional age and eye-hand performance at 12 months corrected age.

B) Specific Objectives

1. Evaluate the effect of gestational age at birth on visual orientation at 40 weeks post-conception by comparing the visual orientation of preterm infants born at different gestational ages.

2. Evaluate the relationship of the preterm infants' visual orientation at 40 weeks post conceptional age with their eye-hand performance at 12 months corrected age.

3. Examine the impact of gestational age at birth, visual orientation at 40 weeks post conception and neurological status at eighteen months corrected age as indicators of eye-hand performance at 12 months corrected age.

Research Null Hypotheses

1. Preterm infants less than 32 weeks gestation at birth do not differ significantly from preterm infants 32-36 weeks gestation at birth in their visual orientation at 40 weeks post-conception.

2. Visual orientation of preterm infants at 40 weeks post conception is not significantly related to eye-hand performance at 12 months corrected age.

3. Gestational age at birth, visual orientation at 40 weeks post-conception, and neurological status at 18 months corrected age are not significantly correlated with eye-hand performance at 12 months corrected age.

CHAPTER II

LITERATURE REVIEW

This review of the literature outlines two subject areas: the development of preterm infants and the development and assessment of infants' visual system and its interaction with motor performance.

Development of Preterm Infants

Preterm infants, by definition, are infants who are born before the completed thirty-seventh week of gestation and live in the extrauterine environment during the fetal period (Gesell et al., 1949; Prechtl & Nolte, 1984). Seven to 10% of all live births in the United States are preterm (Gorski, 1984). Preterm infants are viewed as a unique group of infants with specific characteristics and patterns of development (Aylward, 1981; Paludetto et al.,1984; Prechtl et al., 1979). Indeed, Prechtl & Nolte (1984) define preterm birth as a pathological event.

Preterm infants are challenged to live in an artificial environment during a period that is normally spent in utero. Many investigators have questioned whether this unique environment affects the behavioral and neurophysiological development of the preterm infant. Parmelee (1975) argues that preterm infants have an uneven development of behavior, and the extrauterine experience neither enhances nor retards their development due to the immaturity of their central nervous system. In 1980, Touwen described two opposing theories to explain the development of the central nervous system (CNS) of the preterm infant. The first suggests that the development of the CNS is a genetically preprogrammed process. An uncomplicated preterm birth would not affect the natural course of maturation. This first argument was supported by the earlier studies of Gesell (1933) and Saint-Anne Dargassies (1966) who contend that neurological development is biologically driven. The second theory presented by Touwen (1980) promotes the idea that the brain matures during the last months of fetal life and is environment-dependent. Contrary to Parmelee's (1975) position, Touwen's second theory (1980) suggests that the development of preterm infants may be either enhanced or retarded as a result of the extrauterine experience.

Previously, full-term neonates were thought to be helpless at birth and the environment would be a determinant factor in their development. Current research has shown that infants are born with the ability to actively interact with the environment (Rossetti, 1986). Controversy still exists concerning the classical issue of "nature" or maturational control versus "nurture" or experiential influence in human development. The study of preterm infants facilitates a better understanding of the factors that influence development. According to the "nature" argument the neuromotor development is an innate preprogrammed process and the development of preterm infants following an uncomplicated birth would not be affected by the extrauterine experience. This is much like Parmelee views the preterm birth experience. The "nurture" argument suggests that neuromotor development is affected by the environment and the extrauterine experience caused by preterm birth could either enhance or retard development. This argument runs parallel to Touwen's second theory, discussed above.

Saint-Anne Dargassies (1966) and Gesell (1933) advocate the "nature" viewpoint. Saint-Anne Dargassies (1966) describes the maturational process of preterm infants born from twenty-eight to forty weeks gestation. She reports that ontogenesis evolves according to the inherent biological structures and functions and that the environment does not enrich this process. Touwen (1980) promotes the "nurture" viewpoint and believes that there is evidence of environmental influence on the neurological development of preterm infants.

In agreement with Touwen (1980) many investigators have reported that the development of preterm infants is affected by their environmental experience. As mentioned previously, while a group of investigators contend that the extrauterine experience has a positive effect on specific aspects of preterm infants' development (Baraldi et al., 1981; Kopp et al., 1975; Palmer et al., 1982), another group argues that the environment has a negative impact on the immature structures of preterm infants (Ferrari et al., 1983; Morante et al., 1982). In agreement with the argument given by this last group of investigators Als (1986) presented a model for the dynamic organization of infant behavior in response to the stress imposed by the extrauterine environment. It was theorized that although stress is necessary for development, preterm infants are exposed to an excessive amount of stimuli (stress), which are imposed on their immature central nervous functioning and may result in poor quality of responses. According to this model there is a balanced interaction between the individual's behaviorally observed systems (i.e. autonomic, motor, state organizational, attention and interacting, and self-regulatory balancing systems) that allows the neonate to interact continuously with the environment. Because of the immaturity of preterm infants' nervous system, excessive stress from the NICU environment may jeopardize their behavioral balance and impact negatively on their neurological organization.

As a means of studying the effects of the extrauterine environment on the development of the newborn, several investigators have compared the neurobehavioral functions of low-risk preterm with full-term infants when both groups are forty weeks post-conception. The following studies are some examples of this approach. Ferrari et al. (1983) suggest that low gestational age at birth (less or equal to 33 weeks gestation) is associated with heterogeneous and poor behavioral organization among preterm infants when compared to full-term newborns. Forslund & Bjerre (1983) found the two groups to differ considerably in neurological development, e.g., in muscle tone and active motility. Gorga et al. (1985) report consistent differences between preterm and full-term infants in motor development and quality of movement with the greatest distinctions observed in the first six months of age. Between group differences were also found for activity states with the preterm group exhibiting lower scores (Michaelis et al., 1973). Some explanations for the differences found between low-risk preterm and full-term infants include intervening factors such as body weight, time of the examination of the full-term infants, state of alertness at the time of the examination (Prechtl & Nolte, 1984).

Besides differing from full-terms the preterm population has itself been considered a heterogeneous group of infants (Ferrari et al., 1983; Forslund & Bjerre, 1983). As a result, current studies have been investigating the impact of the extrauterine environment on infants' development by means of comparing preterm infants born at younger gestational ages with those born at older gestational ages. Piper at al. (1989) found that normal preterm infants born at two gestational age groups (less 32 weeks gestation; 32-36 weeks gestation) differed significantly in terms of primitive reflexes at four months corrected age. Also, Piper at al. (in press) reported that these two gestational age groups of preterm infants differed in their fine-motor development at eight and 12 months corrected age. These findings suggest that some aspects of the preterm infants' development are adversely affected by prolonged extrauterine experience.

With recent advances in ultrasound, it is now possible to study the influence of environmental differences on early development by comparing the fetus and the preterm infant at the same conceptional age. Cioni et al. (1986) described the incidence of motor patterns in the fetus and compared them with those of the preterm infant, at the same conceptional age. The results indicate that many items in the motor repertoire of preterm infants are similar to those described in the fetus. While many investigators agree that preterm infants differ from full-terms, there is still disagreement as to how preterm birth and prolonged extrauterine existence impact on specific developmental functions (Ferrari et al., 1983; Forslund & Bjerre, 1983; Gorga et al., 1985; Kurtzberg et al., 1979; Parmelee, 1975; Parmelee & Harber, 1973; Piper et al., 1985; Touwen, 1980). This issue needs to be carefully investigated in order to allow improvement for the developmental outcome of young preterm infants. Recent studies have investigated the impact of preterm birth on later development by examining different groups of preterm infants, instead of comparing their performance with that of full-terms (Piper et al., 1989; Piper et al., in press). This procedure is a step towards a better understanding about the impact that medical technological advances, such as neonatal intensive care units, are having on infants' development, by increasing the life expectancy of very young preterm infants. The present study proposed to examine the the effect of preterm birth on specific aspects of development such as early visual orientation and later eye-hand performance.

Infants' Visual System

Ffooks (1969) defines the visual process as "the reception of information by the retina and the transmission of that coded information along the optic nerve and radiations to the cerebral cortex". In infancy the visual process is in a continuous state of development and interacts with the development of all other motor and sensory systems. Thus, the visual system has an important role in the infants' interaction with the environment (Brazelton et al.,1966).

Vision is one of the most investigated sensory systems. Gorski et al. (1987) describe this system as an interesting paradox. Although the visual system is the least well-developed of any sensory system at birth, and the last to start functioning, it is extremely important in the infant's interaction with the environment. In order to understand the relationship between preterm birth and visual performance, it is essential to study the development and maturation of the structures underlying the processing of visual information.

A) Development and Maturation of the Visual System

The structures of the visual system develop at different periods during gestation and throughout the first years of life.

The retina differentiates during the first trimester of gestation (Gorski et al., 1987). It consists of the fovea in the central region and the periphery. The fovea is comprised of cones that mediate details and color vision (Gorski et al., 1987). Cones within the central retina do not attain full development until at least four months post term (van Holf-van Duin & Mohn, 1984). The periphery of the retina consists mainly of rods that are responsible for the detection of brightness changes and movement (Gorski et al., 1987). The rod cells are the last to develop in utero but at birth are fully functional (Timor-Tritsch, 1986). Differentiation of the foveal region in utero occurs first; however, at birth this region is quite immature, whereas the periphery of the retina is adult-like (Abramov et al., 1982).

The epithelial adhesion between the eyelids breaks down by the end of the fifth fetal month, so the eyes of preterm infants can be opened by 26 weeks gestational age. However, preterm infants usually keep their eyes closed in the first few weeks of life (Timor-Tritsch, 1986). This implies that pattern vision is unlikely before 28 weeks gestation. The pupillary light response is generally present, although slow, by 31 weeks (Finnstrom, 1971), but the dilatory muscle of the pupil is still not totally functional by term (van Holf-van Duin & Mohn, 1984). When considering refraction, van Holf-van Duin & Mohn (1984) report that normal 28 week infants seem to be myopic (image of objects are focused in front of the retina, meaning that infants focus better on near objects; Gouras, 1985), whereas in the last few weeks before term they seem to be hypermetropic (image of objects are focused beyond the retina, allowing better focusing on distant objects; Gouras, 1985). Eye movements, important for tracking moving objects in the visual field, begin in the human fetus between 16 and 18 weeks post-menstrual age and by 20 weeks eye movements become more rapid. However, there is a gradual decline in the percentages of both rapid and slow eye-movements between 32 and 40 weeks gestation (Prechtl & Nijhuis, 1983). Thus, the oculomotor system has been active for about five months prior to the first visual input at term.

The occipital cortex begins to myelinate during the sixth fetal month, and the calcarine portion of the occipital cortex is well myelinated at birth (Brazelton et al., 1966). Myelinization of the optic nerve was first observed in the seventh month of fetal life (Nakayama, 1967). This process appears to be hastened by light exposure (Mellor & Fielder, 1980). Magoo & Robb (1981) describe the process of myelination from the optic tract reaching the globe by term, and significantly increasing in sheath thickness during the first two years of life. The frontal eye fields are not myelinated in the newborn infant. In the adult frontal eye fields are known to contribute to the initiation of voluntary fixation (Gouras, 1985). It is plausible to think that the immaturity of these structures and pathways at birth will affect the optimal performance of infants' visual abilities. According to Grafstein (1963), myelination is not necessary for function but it increases the speed of conduction. It has been suggested that with the influence of light, a preterm infant at 40 weeks post conception will have more advanced myelination of their visual structures than a newborn full-term infant (Hoyt et al., 1982). This suggestion is in agreement with the "nurture" argument described earlier, specially with those investigators who contend that the extrauterine environment has a positive effect on preterm infants' visual functioning (Baraldi et al., 1981; Kopp et al., 1975; Palmer et al., 1982).

Considerable changes occur in major central structures of the visual pathway, such as the lateral geniculate nucleus and the primary visual cortex, during the postnatal period. The lateral geniculate nucleus of the thalamus is the intermediator between the eye and the visual cortex. During fetal as well as early postnatal life the lateral geniculate nucleus neurons show immature features such as numerous dendritic and somatic spines, which will disappear by nine months of age (van Holf-van Duin & Mohn, 1984). In the visual cortex, dendritic growth of neurons starts at twenty-five weeks gestation, is very active around term and continues during the first year postnatal life (van Holf-van Duin & Mohn, 1984).

In early development, the major structural changes within the visual system are followed by functional changes. Most visual functions show changes during the first few months after birth. Although several structures are quite immature at term, they are functional at birth and tend to improve with subsequent maturation. Visual accommodation, defined as the ability to focus objects, is poor in the first month of life, but it improves by the third month, along with the maturation of the pupillary system, the ocular muscles and lens. Acuity is the ability of the visual system to detect various patterned information. It is also poor at birth but shows rapid improvement over the first six months of life, along with the maturation of the foveal region of the retina. Unlike older infants, newborn infants visually track objects by performing saccadic eye movements. By four months of age smooth pursuit eye movements improve along with the maturation of the oculomotor system and thereafter saccades are no longer present in smooth tracking (Gorski et al., 1987).

B) The Effect of Prematurity on the Development of Visual Functions

As has been discussed earlier, the role prematurity plays in development has been the object of intense controversy and investigation. The influence of prematurity on development of visual functions is one component of this controversy particularly pertinent to this project.

In 1981, Friedman et al. reported that the visual system develops throughout pregnancy, and structural changes occur as late as the ninth month of gestation. This structural immaturity results in functional immaturity at term, as described in the previous section. Function is improved with subsequent development. Consequently, Friedman et al. (1981) suggested that the visual system is adversely affected by preterm exposure to the extrauterine environment. As stated earlier, van Holf-van Duin & Mohn (1984) reported that preterm infants are known to have a high incidence of visual problems, and Rossetti (1986) agreed that visual disturbances are present in 44% of the high-risk population, which includes a large number of preterm infants. Indeed, infants born prematurely are exposed to visual stimulation during a period which is unavailable to full-term infants.

The investigation of the effects of extrauterine environment on the development of the newborn by comparing the performance of infants born at term with preterm infants, both usually at 40 weeks gestation, has produced controversy (Cioni et al.,1986). Some studies stress the similarities, others emphasize the differences between preterm and full-term infants.

Ferrari et al. (1983) reported poorer performance by low-risk preterm infants in comparison with full-term newborns, in the areas of visual orientation and alertness, as assessed by the Brazelton Neonatal Behavioral Scale (Brazelton, 1984). Among the infants' behavioral repertoire they recorded inferior performance of visual and auditory orientation, inferior motor performance and poorer regulation of alertness state. Morante et al. (1982) examined pattern vision in preterm and full-term infants using a preferential looking technique. This study was based on the premise that infants prefer to fixate on a patterned visual stimulus than on a homogeneous stimulus. They found that preterm infants at 40 weeks post conception had poorer pattern preferences than full-tenn infants.

Allen & Capute (1986b) found no differences between premature and full-term infants on three visual measures: 1. response to blinking and habituation to light, 2. blinking to a threatening gesture and 3. optokinetic nystagmus. No differences in pupil response, head-turning and blinking to light between preterm and full-term infants at 40 weeks were also reported by Robinson (1966).

Other investigators have found that preterm infants have superior visual performance when compared with full-terms on a forced preferential looking task (Baraldi et al., 1981) and that they show longer visual fixation periods (Kopp et al., 1975). Also, Palmer et al. (1982) reported better visual orientation and alertness state among preterm infants in comparison to full-terms, both at 40 weeks gestation. And, as stated previously, Hoyt et al. (1982) suggest that early visual experience of preterm infants in the period from birth to term may lead to a slight acceleration in the development of the visual system. Paludetto et al. (1982) suggested that the extrauterine environment could have a specific impact on those visual responses which can be influenced by the bright light to which the infants are exposed in the nursery, such as the visual orientation responses measured by the Brazelton Neonatal Behavioral Assessment Scale. Thus support exists for both sides of this argument and it remains unclear whether early exposure to light has a beneficial or harmful effect on infants' visual system.

Another aspect of this controversy relates to the infants behavioral state. The autonomic nervous system mediates the infants' response to the external environment and is responsible for regulating the organization of behavioral states in the infant, among other physiological functions. It has been documented that an infants' behavioral state has an impact on their visual fixation responses (Boismiere, 1977; Hack et al., 1976; Hack et al., 1981). A study by Moseley et al. (1988) suggested that the increase in intensity of illumination within the NICU environment tends to have a deleterious effect on both organization of behavioral state and amount of eyelid opening among preterm infants. Thus, the extrauterine visual stimulation experienced by preterm infants may indirectly affect their ability to respond to a visual stimulus by influencing the infants' behavioral state.

In summary, despite being the last of the sensory systems to have its functional onset, the visual system is very important for interaction with the environment. Consequently, several investigators have studied the impact of preterm birth on the development of the immature structures and functions of the visual system. Although the visual abilities of preterm infants have been widely investigated using different methodologies, no consensus has yet been formed.

C) Assessment Techniques to Measure Visual Function

Most investigators agree that the assessment of visual function in the newborn is an essential part of the neurological examination and is indicative of central nervous system function (Brazelton et al., 1966; Kopp et al., 1975; Morante et al., 1982; Placzek et al., 1985). More specifically, Brazelton (1984) argues that the ability to fixate and follow a visual stimulus can be seen in alert preterm and full-term infants, and any interference with optimal central nervous system function in these infants may reduce their ability to elicit these integrated visual responses. However, he also contends that although the elicitation of visual focusing and tracking has been found to be predictive of later normal central nervous system function, the lack of response is not necessarily an indicator of future dysfunction.

One of the most important functions of the visual system is to detect patterned information (Gorski et al., 1987). Pattern detection refers to the ability to perceive that a stimulus is patterned in contrast to being unpatterned or uniform, and is often assessed using tests of visual acuity (Banks & Salapatek, 1983; Gorski et al., 1987). The three commonly used techniques to assess visual acuity in the neonatal period, are: optokinetic nystagmus (OKN; Gorman et al., 1957), preferential looking (PL; Atkinson et al., 1977; Fantz, 1963; Teller et al., 1974;), and visually evoked potential (VEP; Norcia & Tyler, 1985). The investigations using all of these techniques have indicated that the visual acuity of infants increases between birth and six months (Dobson & Teller, 1978).

OKN is defined as "the involuntary series of eye movements elicited by a succession of objects passing across the visual field" (Dobson & Teller, 1978, p. 1469). The eye movements present in OKN consist of two parts: a slow fixation phase, when the eyes follow the stimulus, and a fast corrective phase in the opposite direction (Gorman et al., 1957). In this technique, acuity is measured binocularly while the infant is positioned supine in a crib looking up at a canopy of black and white stripes. The stripes move in 180 degree-arc across the infant's visual field, and the evaluator looks for the smallest stripe width which elicits OKN (Hoyt et al., 1982). This technique requires that the infant be awake with open eyes.

The preferential looking technique was developed by Fantz (1963) on the assumption that infants fixate on patterned surfaces more than homogeneous surfaces. Pattern preference appears after 34 weeks gestation (Dubowitz, 1979). This technique requires the infant to fixate differentially on various pair of stimuli presented within the visual environment (Dobson & Teller, 1978). The reflection of the visual stimulus in the infants' pupil is observed and both the number of times and duration of fixation on the visual object are recorded. The preferential looking technique is the most common procedure used to document the visual acuity of young infants and some interesting findings have been reported. Using the preferential looking technique, Fantz (1963) showed that during the early months of life infants have greater visual interest for patterns than for plain colors, and their interest increases if the pattern is similar to that of a human face. In 1977, Atkinson et al. reported that infants show a preference for moving versus stationary patterns. This procedure has been used to assess preferences in full-terms as well as in preterm infants (Dubowitz et al., 1980; Morante et al., 1982).

Visual evoked potential (VEP) consists of "monitoring the activity of the visual cortex in response to visual information processed by the retina and by the visual pathway" (Norcia & Tyler, 1985, p. 1399). It is recorded by placing electrodes on the scalp over the occipital region, where the visual cortex is located. The VEP technique shows part of the activity of the visual cortex in response to visual information processed by the retina (Norcia & Tyler, 1985). Some investigators prefer this technique to evaluate the visual system because it is not dependent upon a motor response (Hrbek & Mares, 1964; Hrbek et al., 1973; Norcia et al., 1987; Watanabe et al., 1972). VEPs can be elicited by either a flash of light or by visual fixation on patterned stimulus. Evoked potential is not a common procedure to measure visual abilities in young infants since it requires the child to be immobile and sedated.

In addition to these techniques, function within the visual system is also assessed through clinical procedures (see Table 1). For example, the pupillary light response indicates the functioning state of afferent and efferent pathways, and it is usually present by 31 weeks gestation (Robinson, 1966). The blink to light and to threat are both learned reflexes; the first may be attained by 30 weeks gestation, but the later develops in normal full-term infants from 16 weeks postnatally (Hoyt et al., 1982). Head turning to light, which is a gross measure of visual acuity, begins between 32 and 36 weeks gestation (Finnstrom, 1971). The ability to fixate and follow a target is also known as visual orientation and is one of the principal tests employed to assess central visual function in infants (Dubowitz, 1979).

Visual orientation has been used to document the visual function of preterms (Dubowitz, 1979) and full-term neonates (Brazelton, 1984). Dubowitz (1979) argues that by 34 weeks gestation preterm infants show maturity of visual orientation responses which are comparable to those seen in full-term infants. Both Brazelton (1984) and Dubowitz (1979) agree that visual orientation responses in the newborn preterm and full-term infants can be used not only as a parameter of visual function but also of neurological maturity. Visual orientation has been used as a means of comparing the responses of preterm with full-term infants, but the literature is controversial. Forslund & Bjerre (1983) reported that by term, preterms showed significantly better ability to focus and follow a red ball than full-term infants. Conversely, Ferrari et al. (1983) found inferior visual orientation performance by preterms when compared with full-term neonates. Visual orientation responses are known to be influenced by infants' behavioral state (Gorski et al., 1987). According to Hack et al. (1976) visual fixation requires an increase in infants' alertness and attentiveness, and is often followed by other behaviors such as eye opening, interruption of sucking, and decrease in general motor activity. There is a suggestion that early visual orientation may be related to later cognitive functioning. According to Wolff (1965), because of the complexity in the ability to visually follow an object, there may be a functional continuity between early visual orientation responses and cognitive function in the child and adult.

TABLE 1

Maturation of Visual Abilities by Gestational Age

GESTATIONAL AGE	VISUAL ABILITIES
30 weeks post-conception	BLINK TO LIGHT
31 weeks post-conception	PUPILLARY LIGHT REFLEX
32-36 weeks post-conception	HEAD TURN TO LIGHT
After 33 weeks post-conception	FIXATE AND FOLLOW A TARGET
16 weeks post-term	BLINK TO THREA

One important aspect to be considered when measuring visual performance in infants is the control of confounding parameters that can influence the results. Gestational age and behavioral state are factors that should be taken into consideration when assessing the visual system. Tilford (1976) and van Holf-van Duin et al. (1983) argued that gestational age at the time of the assessment is an important factor that may interfere with the results. They suggested that when measuring the visual acuity of preterm infants one should consider their conceptional age rather than chronological age, since acuity development in preterm infants is related to age after conception. Accordingly, Dobson et al. (1980) contend that visual acuity screening in preterm infants should be carried out following infants' post conceptional age, instead of postnatal age.

Relative to behavioral state, Brazelton et al. (1966) claimed that the alertness state of the newborn at the time of the assessment may interfere with his/her visual response. According to Wolff (1965) the state of quiet alertness, where the infant is awake, inactive and has his/her eyes opened is the ideal state to assess visual responses in infants. This behavioral state allows the infant to respond adaptively and selectively to the environment (Hack et al., 1976).

Most of the studies cited earlier accounted for gestational age by assessing the visual abilities of preterms and full-terms, both at 40 weeks gestation, and also by correcting for prematurity when following preterm infants longitudinally. However, fewer studies reported the behavioral state at the time of the assessment, and for that we may question their results.

Interaction Between Visual System and Motor Development in Infancy

Sensation and movement have been closely linked. Gesell et al. (1949) stated that the improvement of visual functions must be interpreted in terms of motor maturation as "vision and movement are components of a highly organized sensorimotor integration of stimuli in the central nervous system" (p. 54). The study of visual function has historically focused on either the medical model concerning visual acuity, or the educational model regarding visual perception (Erhardt, 1987). Recently, investigators have also focused on the visual motor coordination, specifically the association between eye and hand, which influences the development of both prehension and vision as well as the development of exploratory functions (Erhardt, 1987).

Eye-hand coordination is known to be an integrated sensorimotor skill and has been defined as "the ability of hands and fingers to go exactly to the places where the eyes inform the brain that they should go" (Ayres, 1979, p. 64). It is known that the visual motor coordination required for reaching towards an object requires the visual perception of the object and motor abilities as well as the ability to associate visually perceived information with motor behavior (Lockman et al., 1984).

In the past investigators were interested in the neonate's reflexive patterns as a critical tool in assessing the integrity of the central nervous system (Allen & Capute, 1986). The coordination between visual and prehensile activities was thought to develop only gradually in ontogenesis, as an outcome of reflex activity (Gesell & Amatruda, 1964; Piaget, 1952). For example, the voluntary reaching and grasping which are necessary for the infant manual exploration of objects was believed to develop from the rudimentary proprioceptive grasp reflex. This traditional reflex-to-voluntary behavior model of development has been questioned and an alternative hypothesis suggested. This hypothesis proposes that antecedents of voluntary behavior are distinct from reflex functions (McDonnell, 1979). This model has given support to studies investigating reaching abilities of newborn infants (Field, 1977; Hofsten, 1982; McDonnell, 1979). Hence, researchers are now turning their attention to precursors of volitional behavior in infancy.

During the past two decades, research has demonstrated that infants' discriminative capacities are more developed during the first year of life than had previously been thought. Hofsten (1982) found in the newborn a rudimentary form of eye-hand coordination which has an attentional function, rather than a manipulative function. According to the findings reported in the study, there is an increased amount of forward extended arm-hand movements when the infant visually fixates an object, suggesting the existence of a close relationship between arm-hand activity and visual fixation. Hofsten suggested that a coordination between eye and hand exists in the newborn, and although it is evident that the catching, grasping, and manipulation functions of eye-hand coordination are not fully developed in the neonate, he/she has the ability to direct his/her eyes and hands towards the external object that was visually detected. McDonnell (1979) looked at patterns of eye-hand coordination in the first year of life and reported that hand movements in infants under eight weeks of age are progressively coordinated with visual stimuli. The observations are also consistent with the hypothesis that "eye-hand activities may emerge concurrently with the maturation of reflex functions, rather than in transition from reflexes" (McDonnell, 1979, p. 255).

Recent investigations suggest that premature infants differ among themselves and also from full-term infants in their performance on fine-motor abilities. Field et al. (1981) followed a group of preterm infants with respiratory distress syndrome. At eight months corrected age they reported delays on items requiring fine-motor skills, as measured by the Bayley Mental Scale. Similarly, Piper et al. (in press) compared two gestational age groups of neurologically normal preterm infants at eight and 12 months chronological and corrected ages. Even when correction for prematurity was performed, infants born at very early gestational ages (less 32 weeks gestation) differed significantly in their fine-motor development when compared with preterm infants born at older gestational ages (32-36 weeks gestation). Ungerer & Sigman (1983) observed that preterm infants performed significantly poorer than full-term infants on items concerning visual information-processing and/or perceptual-motor skills, at three years of age. Their findings suggest that impairments in visual processing may underlie delays in sensorimotor functioning that are identified in later school years. Ross (1985) used the Bayley Scales to compare the performance of preterm with full-term infants, at one year corrected age. She noted that premature infants were less likely to succeed on items testing eye-hand coordination, imitation, and vocalization. These deficits may be seen as early precursors of the difficulties in perceptual-motor abilities that have been found in school age children who were born prematurely (Hunt, 1981; Siegel, 1983).

Visual fixation by preterm infants, at term, has been investigated as a potential predictor for later developmental outcome. Sigman & Beckwith (1980) examined the relationship between preterm and full-term infants' visual fixation at term with caregiver-infant interaction at one month and with developmental outcome at two years, as measured by the Bayley Mental Scale. Surprisingly, there was a significant negative correlation found between the amount of early visual fixation and the scores on the Bayley Scale, at two years. This negative relationship was reported among the preterm group but not among the full-term infants. Besides attributing the negative relationship to a weakness in the study methodology, the authors also question whether sustained fixation should be considered as optimal visual response or if it simply reflects the slower processing of young preterm infants. Further longitudinal studies are needed to explain the poor developmental performance that has been reported in this and other investigations, among preterm infants.

As preterm infants have been found to show poor fine-motor performance at one year, it is now time to investigate this problem more carefully, in an attempt to identify early predictors that might account for this specific poor performance. It is still unknown whether the extrauterine experience or the early visual stimulation received from the environment can account for the later fine-motor difficulties reported among preterm infants. Therefore, the relationship between preterm birth, early visual processing, and later fine-motor performance should be examined more carefully.

Summary

In summary, some differences in the neurobehavioral performance can be identified when preterm infants are compared with full-term infants. Thus, preterm infants should be considered unique with their own abilities and patterns of development rather than being classified as abnormal when compared with full-term newborns. The role of the prolonged extrauterine environment in explaining these differences in development is still unclear.

Studies of the development of preterm infants have included descriptions of the maturational process of their visual functions. Adequate visual abilities of the neonate are viewed as positive evidence of the integrity of the central nervous system. As vision and movement seem to interact early in the process of development, Hoyt et al. (1982) suggest that visual impairment in infancy may result in maturational delays of motor skills and socialization.

During the first two years of life the child interacts with the environment through his/her sensations and motor responses, with the emphasis being on sensory, motor, and manipulative experiences. Thus, eye-hand coordination, as part of the child's sensorimotor repertoire, is an important milestone in the child's early exploratory skills.

Infants born before term show lowered performance on items measuring mental and fine-motor abilities, specially at school age. Preterm infants have been investigated for their abilities at birth and have been followed longitudinally in an attempt to identify early indicators of their "non-optimal" fine-motor outcome. Early identification of potential difficulties in specific areas of development may be useful in signaling the need for careful observation of these children's development, as well as in suggesting the need for early remediation of identified and associated difficulties. Thus, given a potentially positive relationship between early visual functioning and subsequent fine-motor ability, early visual-manipulative-related activities might be emphasized during intervention in order to minimize emergence of fine-motor problems later on the development.

As described by Ayres (1979), the sequence of development follows a "building blocks" pattern where primary levels of organization become the basis for more complex and mature acquisitions. Information concerning the possible relationship between early visual performance in preterm infants and later, more organized and complex functions, such as eye-hand abilities is lacking. The investigation of such relationship might explain some aspect of the poor fine-motor performance reported among preterm infants.

CHAPTER III

METHODS AND PROCEDURES

Study Design

A prospective correlational study design was used in order to gather information about the relationship among the variables being studied (Smith & Glass, 1987). A prospective study has a number of advantages when compared with a retrospective design; in particular it decreases the possibility of subjective bias in obtaining the information (Lilienfeld & Lilienfeld, 1980).

Study Participants

The present study utilizes secondary data from the study entitled "Impact of preterm birth on the neuromotor development of the premature infant", whose primary investigator is Dr. M. C. Piper. The data were collected between 1985 and 1987. The objective of the original project was to evaluate the impact of preterm birth on the neuromotor development of premature infants, according to their adjusted and chronological ages.

The subjects of this study were preterm infants less than 36 weeks gestation at birth who have received neonatal care at the neonatal intensive care unit of the University of Alberta Hospitals, in Edmonton. Infants with congenital abnormalities were excluded. Gestational age was determined from maternal history of the last menstrual period and confirmed by early ultrasound if available, or by the Dubowitz technique (Dubowitz et al., 1970).

Infants with informed parental consent (Appendix A) were assigned to one of the two preterm groups, according to their gestational age at birth:

Group 1: Infants born at less than 32 weeks of gestation;

Group 2: Infants born between 32 and 36 weeks of gestation.

Data Collection Procedure

The present study considered data collected from assessments performed on all participating infants according to the following schedule:

1. At 40 weeks gestational age: The Neurological Assessment of the Preterm and Full-Term Newborn Infant (Dubowitz & Dubowitz, 1981; Appendix B), which includes an item to measure visual orientation;

2. At 12 months corrected age: The Griffiths Mental Developmental Scales (Griffiths, 1954; Appendix C), which includes a subscale to measure eye-hand performance.

3. At 18 months corrected age: The incidence of cerebral palsy and other neuromotor disorders was determined through a neurological examination performed by a developmental pediatrician. The Neurological Examination of the Collaborative Perinatal Project (Hardy et al., 1979) was used to assess the incidence of neuromotor disorders in this cohort of infants.

Corrected age was determined by subtracting the number of weeks the infant was born before term from his/her chronological age.

The first two assessments were performed by one therapist who was pretrained in the administration of the assessment tools and who was "blind" to the gestational age at which the infant was born in order to avoid any bias concerning the his/her general performance. The developmental pediatrician who performed the neurological assessment at 18 months corrected age was also kept "blind" to the children's gestational age at birth as well as to their medical histories.

Measures

A) The Neurological Assessment of the Preterm and Fullterm Newborn Infant

The Neurological Assessment of Preterm and Full-Term Newborn Infants was designed by Dubowitz & Dubowitz (1981) in an attempt to combine both neurological and neurobehavioral examinations into one practical and objective evaluation that can be performed within a short period of time. This tool is applicable for full-term as well as preterm infants and is also used for sequential examinations of preterm infants.

The assessment tool consists of two items on habituation (auditory and visual); 16 items on posture, movement, and tone; five primitive reflexes; and seven neurobehavioral items. There are also some general observations such as eye movements and character of cry. Responses are not graded as normal or abnormal; rather, each item has a maximum of five grades of responses.

Many items have been borrowed from previous assessments and therefore, the content validity has been established previously (Pelletier & Lydic, 1986). Tests of predictive validity have demonstrated a good correlation between 40 weeks postmenstrual age and neurological outcome at one year (Dubowitz et al., 1984).

Although no reliability studies have been conducted, the authors note in the manual that the assessment has shown good inter-observer correlations between pairs of observers examining the same baby independently (Dubowitz & Dubowitz, 1981). Since this test is not norm-referenced, norms are not available.

Visual performance was measured with the visual orientation item from the neurobehavioral section of this neurological assessment. The selected item was borrowed originally from the visual function part of the Neonatal Behavioral Assessment Scale (Brazelton, 1984). In this item the infant is assessed for his/her ability to focus and fixate on a red woollen ball, and to track (follow) it. Five responses are possible for this item:

1. The infant does not focus or follow stimulus.

2. Stills; focuses on stimulus; may follow 30° jerkily; does not find stimulus again spontaneously.

3. Follows 30-60° horizontally; may lose stimulus but finds it again. Brief vertical glance.

4. Follows with eyes and head horizontally and to some extent vertically with frowning.

5. Sustained fixation; follows vertically, horizontally, and in circle.

The responses of the visual orientation item require greater levels of maturation of the visual system as they increase from response 1 to response 5, according to the grading description. The visual orientation of the preterm infants was classified as either "optimal performance" or "non-optimal performance". A grade equivalent to columns 3, 4 or 5 was defined as "optimal performance". A score on columns 1 or 2 was considered as a "non-optimal performance". These criteria were based on the findings that the score of 3 was the most frequent visual orientation response and therefore it was considered an "optimal" response and used as a baseline; the scores which required less mature response (1 and 2) were then considered "non-optimal". Also, according to Dubowitz & Dubowitz (1981) most preterm infants can be expected to track horizontally, vertically and in circle at 40 weeks post conception.

B) The Griffiths Mental Developmental Scales

The Griffiths Mental Developmental Scales were designed to assess the level of mental development of babies and young children from birth to eight years of age. The Scales provide developmental quotients and mental ages for five developmental domains: locomotor, personal-social, hearing and speech, eye-hand, and performance, as well as an overall development quotient. Each subscale contains 52 graded items for the first two years of life based on three items for each month of life in the first year, and two items for each month in the second year. This tool was standardized on British children (Griffiths, 1954). A further use of this assessment has been to evaluate the outcome of intervention programs (Smith et al., 1980).

The eye-hand subscale was used to measure eye-hand performance of the preterm infants at 12 months of age. Inter-rater reliability of the eye-hand and the performance subscales have been found to show greater consistency (r falling between 0.6 and 1.0) than the other subscales in this assessment (Smith et al., 1980).

Developmental scores are translated into mental ages and quotients for the eye-hand subscale. The mental age for each infant is given by multiplying by five the total score of items passed by the child in the first year of life (as there are roughly five weeks in each month). The result is divided by three (as there are three items in the scale for each month during the first year of life). Because some children may pass items for the second year of life, mental ages are calculated separately for the second year of life, and the results are added to the first year, to give the mental age for the subscale.

$$\text{Mental Age 1 (M.A. 1) for the 1st year} = \frac{\text{items passed x 5}}{3} \text{ weeks}$$

$$\text{Mental Age 2 (M.A. 2) for the 2nd year} = \frac{\text{items passed x 5}}{2} \text{ weeks}$$

$$\text{M.A.} = \text{M.A.1} + \text{M.A.2}$$

The developmental quotient for the subscale of eye-hand (DQ E-H) was obtained by multiplying the infant's mental age by one hundred and dividing the quotient by the child's corrected age (C.A.) at the time of the assessment.

$$\text{DQ E-H} = \frac{\text{M.A. X 100}}{\text{C.A.}}$$

A developmental quotient equal to or greater than 100 is considered to be normal.

C) Neurological Examination of the The Collaborative Perinatal Project

The Neurological Examination of the Collaborative Perinatal Project involves a complete pediatric examination, including a detailed assessment of neurological function and developmental skills (Hardy et al., 1979). A judgement is made as to whether the child is normal, suspect, or abnormal in each of two categories, named neurological status and non-neurological status, which includes all other aspects of the pediatric evaluation. For this study, the outcome used was neurological status.

Ethical Considerations

1. The parents of all infants were required to sign an informed consent form (Appendix A) prior to data collection procedure.

2. Confidentiality is guaranteed by reporting each subject with a given identification number, rather than by name. Only the project coordinator and the principal investigator of the original research have access to a master list which relates study numbers to names. All children will remain anonymous throughout the study.

3. Data will be reported as group data in any presentation of the results found in this study.

Limitations of the Study

A) Methodological Limitations

1. This is an observational study and for that reason no assumptions about cause and effect relationships between independent variables are warranted.

2. Eye-hand coordination is functionally important at preschool age and consequently some aspects that might be not apparent at 12 months may appear later in fine-motor development.

3. This is a secondary data study and for that reason no major changes can be made concerning the data collection procedure.

4. The assessment tools used in this study have not been completed validated. However, other authors have used them with the preterm population (Dubowitz et al., 1980; Piper et al., in press).

5. The allocation of preterm infants to gestational age groups and to visual orientation categories was an arbitrary procedure and they may not translate the optimal way of examining difference between groups.

B) Limitations in Data Collection

1. Infants were assessed on only one occasion. The scores obtained may be affected by factors such as test environment, time spent to arrive at the place of the test, time since last fed, as well as some physiological needs of the child.

2. The examiner's face as well as any auditory stimulation may have distracted the infant and interfered with the response to the visual orientation assessment.

3. The reliability coefficient for the present data is unknown.

Data Analyses

Mann-Whitney U test was used to test for the difference between the two groups of infants born at different gestational ages (less than 32 weeks; between 32-36 weeks) in their actual visual orientation scores from the Neurological Assessment of the Preterm and Fullterm Infant (1, 2, 3, 4, and 5). Chi-Square analysis was applied to test whether the two gestational age groups of infants differed according to their visual orientation performance at 40 weeks post conception (optimal; non-optimal).

Jaspen's M coefficient of multiserial correlation was used to examine the strength of the relationship between the visual orientation scores of preterm infants at 40 weeks post conception (1, 2, 3, 4, and 5) and their eye-hand developmental quotients at 12 months corrected age. The Jaspen's M is the appropriate correlation coefficient to examine the association between one ordinal variable, in this case visual orientation scores, with another variable from an interval scale, such as the eye-hand developmental quotients (Champion, 1981). Unpaired t-test was the analysis used to test the difference between the two groups of infants classified according to visual orientation at 40 weeks post conception (optimal; non-optimal), on their eye-hand developmental quotients at 12 months corrected age. This analysis was also used to test the difference between the two gestational age groups (<32 weeks; 32-36 weeks) on their eye-hand developmental performance at 12 months corrected age.

As recommended by Kerlinger (1986), multiple regression analysis is the appropriate procedure for factorial designs having unequal number of cases in each cell. Stepwise multiple regression analysis was employed to test which variables (gestational age at birth; visual orientation at 40 weeks post conception; neurological status at 18 months corrected age) accounted for the most variance in eye-hand developmental quotients at 12 months corrected age.

The statistical analyses were initially carried out with the total sample of preterm infants (N= 73). Subsequently, the same analyses were performed with the 45 infants who were assessed as being neurologically normal at 18 months corrected age. This procedure minimizes the bias associated with including those infants who were either neurologically suspicious or abnormal.

All statistical analyses were tested at the 0.05 level of significance.

CHAPTER IV

RESULTS

CHARACTERISTICS OF STUDY SAMPLE

Initial data were collected on 120 preterm infants. The eighteen month neurological assessment was completed on 73 of the original 120 infants. This study has analyzed the data from those 73 infants.

Of the 47 dropouts, two infants died and the remaining infants either moved or lived too far away to return for the 18 month assessment. Most of the infants who were not from Edmonton were born in small towns within the province of Alberta. After being born, they were transfered from their towns to the University of Alberta Hospital, mainly because of postnatal complications and absence of appropriate medical resources in their towns. Therefore, from the original 120 infants, the 47 dropouts, as a group, are those infants who are most likely to have had serious perinatal problems.

Of the 73 infants who comprised the study sample, 38 were males and 35 were females. These infants were then assigned to one of two groups according to gestational age (G.A.) at birth: less than 32 weeks gestation (n= 34), and 32-36 weeks gestation (n= 39). The frequencies of gestational ages, birthweights, and gender for each of the two gestational age groups are provided in Table 2.

The neurological outcomes at 18 months corrected age for infants in the two gestational age groups are documented in Table 3.

The frequencies of the visual orientation scores for the 73 infants, as assessed with the Neurological Assessment of the Preterm and Fullterm Newborn Infant (Dubowitz & Dubowitz, 1981) at 40 weeks post-conceptional age, are illustrated in Figure 1. The visual orientation scores were then combined and classified into two categories: "non-optimal" (scores 1 and 2; n=18), and "optimal" (scores 3, 4, and 5; n=55). See the Methods section (p. 29) for the rationale for combining groups.

TABLE 2

Frequencies of Gender, Gestational Age and Birthweight by Gestational Age Group

CHARACTERISTIC	GESTATIONAL AGE GROUP			
	< 32 WEEKS(n=34)		32-36 WEEKS (n=39)	
GENDER				
MALE	16	(47.06%)	22	(56.41%)
FEMALE	18	(52.94%)	17	(43.59%)
GESTATIONAL AGE				
25-27 WEEKS	9	(26.47%)	-	
28-29 WEEKS	15	(44.12%)	-	
30-31 WEEKS	10	(29.41%)	-	
32-33 WEEKS	-		19	(48.72%)
34-36 WEEKS	-		20	(51.28%)
BIRTHWEIGHT				
< 750 gm	2	(5.88%)	-	
750-1000 gm	9	(26.47%)	-	
1001-1500 gm	16	(47.06%)	4	(10.26%)
1501-2500 gm	7	(20.59%)	32	(82.05%)
> 2500 gm	-		3	(7.69%)

TABLE 3

Neurological Outcome at 18 Months According to Gestational Age Groups

NEUROLOGICAL OUTCOME	GESTATIONAL AGE GROUP < 32 WEEKS(n=34)	32-36 WEEKS(n=39)
NORMAL	18 (52.94%)	27 (69.23%)
SUSPICIOUS	8 (23.53%)	11 (28.21%)
ABNORMAL	8 (23.53%)	1 (2.56%)

INFERENTIAL ANALYSES

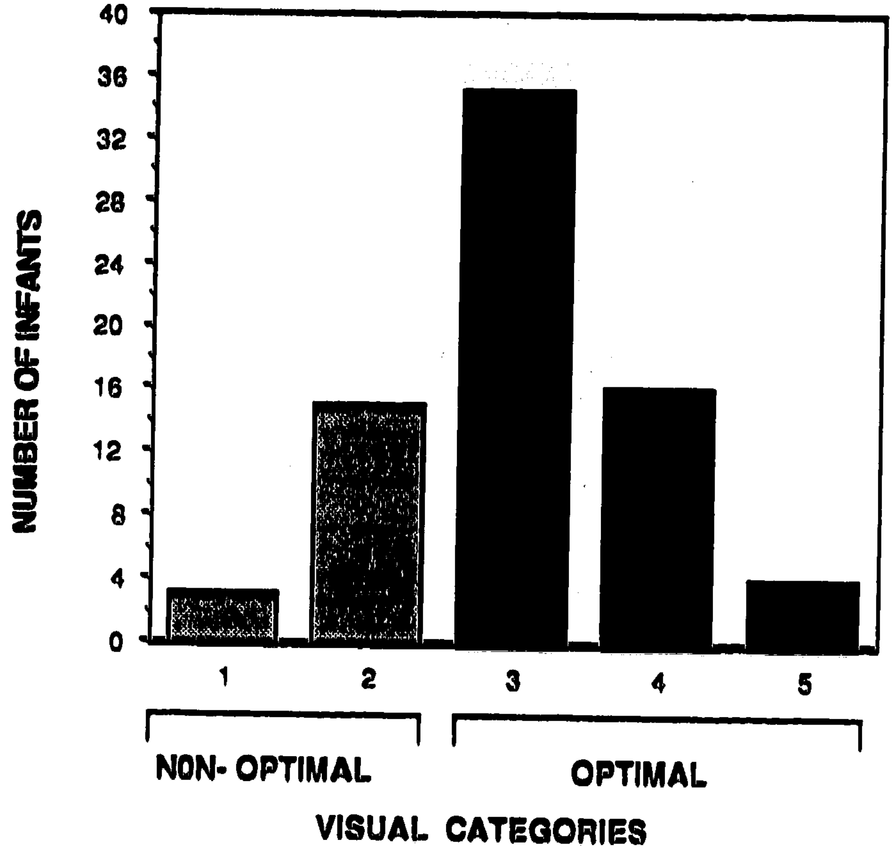
I. Comparison of G.A. groups on visual orientation at 40 weeks PCA

The two gestational age groups (<32 weeks; 32-36 weeks) were compared on their visual orientation scores at 40 weeks post-conceptional age (PCA), by first conducting a Chi-Square analysis. For the Chi-Square analysis, the visual orientation scores were combined into two categories: "non-optimal" (scores 1 and 2; n= 18), and "optimal" (scores 3, 4, and 5; n=55). The observed frequencies varied significantly (p= 0.049) from the expected frequencies. Infants born 32-36 weeks gestation were more likely to perform "optimally" than infants less than 32 weeks gestation at birth. Conversely, infants born less than 32 weeks gestation were more likely to perform "non-optimally" than infants 32-36 weeks gestation at birth. See Table 4 and Figure 2.

A Mann-Whitney U test was then conducted to compare the two gestational age groups (<32 weeks; 32-36 weeks) on the actual scores obtained on the visual orientation item (1, 2, 3, 4, or 5). The Mann-Whitney U is known to be a powerful non-parametric test of significance for difference between two independent groups, on an ordinal characteristic, such as the visual orientation scores (Champion, 1981). Infants born

FIGURE 1

Frequency of Visual Orientation Scores



Legend for Visual Orientation Scores:
1= The infant does not focus or follow stimulus
2= Stills; focus on stimulus; may follow 30° jerkily; does not find stimulus again spontaneously
3= Follows 30-60° horizontally; may lose stimulus but finds it again. Brief vertical glance
4= Follows with eyes and head horizontally and to some extent vertically with frowning
5= Sustained fixation; follows vertically, horizontally, and in circle

TABLE 4

Comparison of Gestational Age Groups by Visual Orientation Categories

(X^2= 3.88; p= 0.049; df=1††)

VISUAL ORIENTATION CATEGORIES	GESTATIONAL AGE GROUP <32 WEEKS (n=34)		32-36 WEEKS (n=39)	
OBSERVED FREQUENCIES†				
OPTIMAL	22	(64.71%)	33	(84.62%)
NON-OPTIMAL	12	(35.29%)	6	(15.38%)
EXPECTED FREQUENCIES†				
OPTIMAL	25.62	(75.35%)	29.38	(75.33%)
NON-OPTIMAL	8.38	(24.65%)	9.62	(24.67)

† Significantly different at $p < 0.05$
†† df= degrees of freedom

TABLE 5

Frequencies of Visual Orientation Scores According to Gestational Age Groups

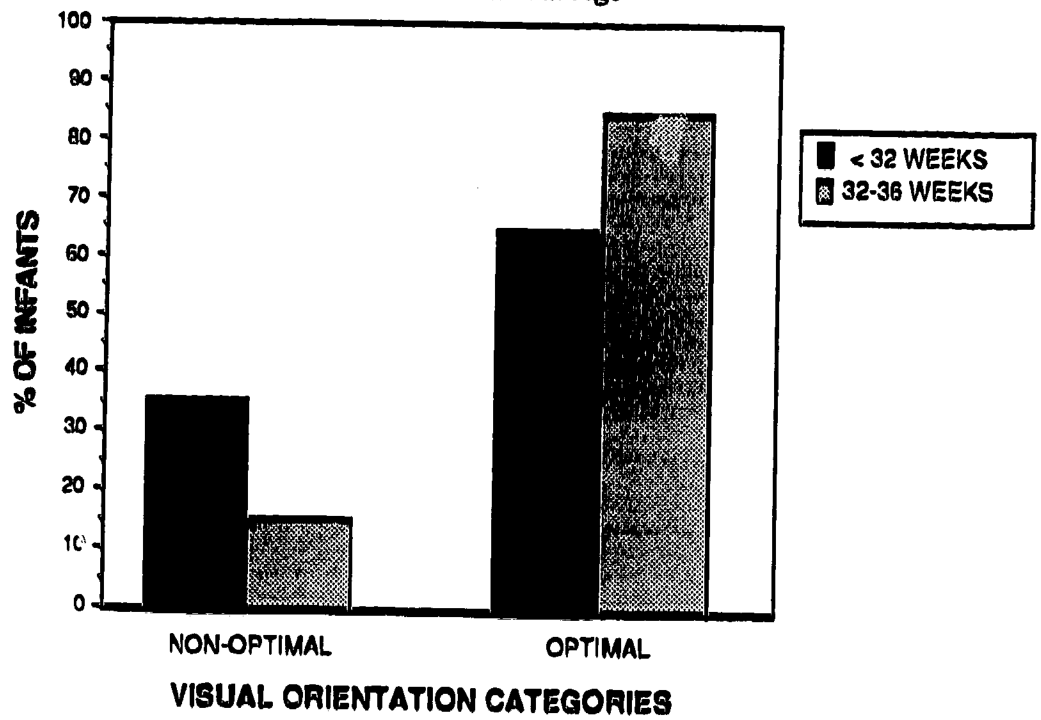
(z= -2.65; p= 0.008)

VISUAL SCORES	GESTATIONAL AGE GROUP <32 WEEKS (n=34)		32-36 WEEKS (n=39)	
1	2	(5.90%)	1	(2.60%)
2	10	(29.40%)	5	(12.80%)
3	18	(52.90%)	17	(43.60%)
4	3	(8.80%)	13	(33.30%)
5	1	(2.90%)	3	(7.70%)

between 32-36 weeks gestation achieved significantly ($p= 0.008$) higher scores in visual orientation than the group of infants born at < 32 weeks gestation ($U= 423$). The results are reported in Table 5.

FIGURE 2

Observed Frequencies of Visual Orientation at 40 Weeks Post-Conception According to Gestational Age



II. Comparison of Optimal/Non-Optimal Visual Orientation Categories (40 weeks PCA) on Eye-Hand Performance at 12 months

Eighteen of the 73 infants (24.66%) had scores of 1 or 2 (non-optimal visual orientation), and fifty-five of the 73 infants (75.34%) had scores of 3, 4, or 5 (optimal visual orientation); see Figure 1. An unpaired t-test was conducted to compare the "optimal" infants with the "non-optimal" infants, on eye-hand performance at 12 months corrected age. Preterm infants who had "optimal" visual orientation at 40 weeks PCA did not differ significantly ($p=0.67$; $df=71$) from those who had "non-optimal" orientation, in terms of their eye-hand performance at 12 months corrected age. See Table 6 and Figure 3.

TABLE 6

Eye-Hand Developmental Quotients According to Visual Orientation Categories

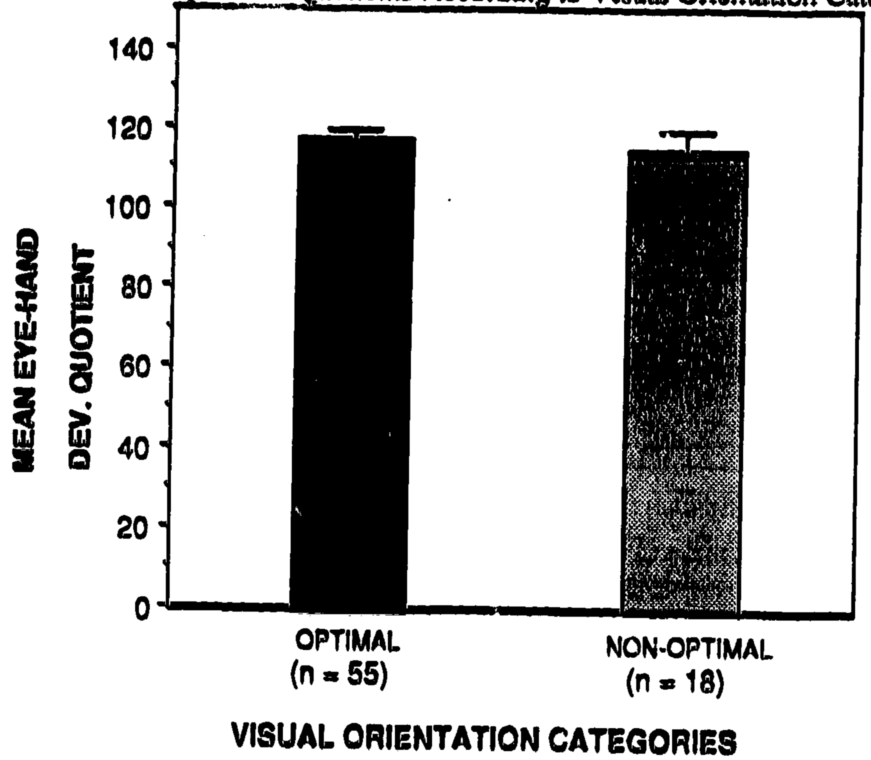
CHARACTERISTIC	MEAN EYE-HAND QUOTIENT	t VALUE (unpaired)	p VALUE (2-tail)
VISUAL ORIENTATION		-0.43	0.67
OPTIMAL (n = 55)	116.75 (SD: 17.08)		
NON-OPTIMAL (n = 18)	114.69 (SD: 18.97)		

SD: Standard Deviation

Jaspen's M coefficient of multiserial correlation was calculated to compare the actual visual orientation scores at 40 weeks (1, 2, 3, 4, and 5) with eye-hand developmental quotients at 12 months corrected age, for all 73 infants. The Jaspen's M is often used to examine the association between one variable measured in an ordinal scale, in this case visual orientation scores, and another measured in an interval scale, such as the eye-hand developmental quotients (Champion, 1981). The calculated coefficient was $r_{(M)}= 0.13$, revealing that visual orientation scores at 40 weeks PCA were not correlated with eye-hand developmental quotients at 12 months corrected age ($p=0.31$). The scattergram in Figure 4 shows a positive tendency in the relationship between visual orientation scores at 40 weeks and eye-hand performance at 12 months, however, this relationship was not found to be statistically significant.

FIGURE 3

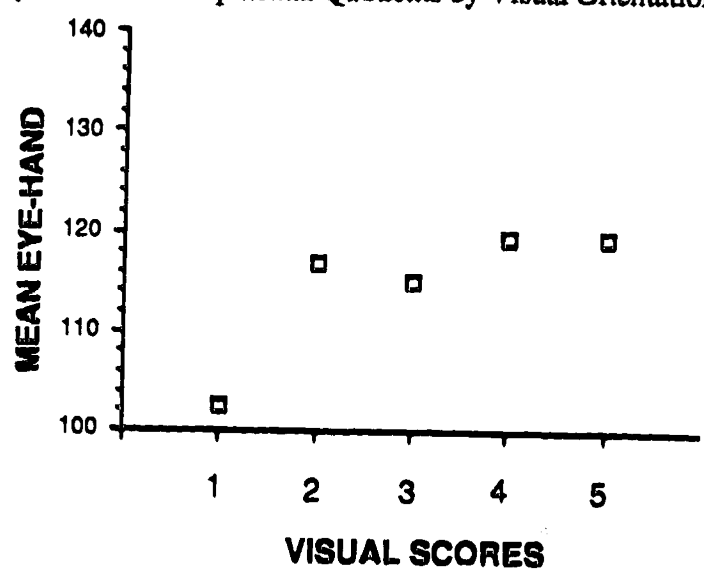
Eye-Hand Developmental Quotients According to Visual Orientation Categories



Error bars= 1 standard error of the mean

FIGURE 4

Mean Eye-Hand Developmental Quotients by Visual Orientation Scores



III. Difference Between Gestational Age Groups on Eye-Hand Performance at 12 months

In order to test whether the 2 gestational age groups (<32 weeks; 32-36 weeks) differ significantly on their eye-hand performance at 12 months corrected age, an unpaired t-test was conducted. The findings show that infants born between 32-36 weeks gestation had significantly higher ($p=0.0004$; $df=71$) eye-hand performance at 12 months corrected age than infants born at <32 weeks gestation. The descriptive results are reported in Table 7.

IV. Stepwise Multiple Regression Analysis for Eye-Hand Performance at 12 months

A stepwise multiple regression analysis was performed to determine which variable or combination of variables were associated with eye-hand performance at 12 months. In stepwise multiple regression the independent variable with the strongest association with the dependent variable is entered first, if it meets the entry requirement (probability of F-to-enter less than or equal to the default value of 0.05). Then, each of the remaining independent variables not in the equation is examined for entry. If the entry criterion is met, the second variable is selected based on the highest partial correlation with the dependent variable (Norusis, 1983). The process continues until there are no other variable that meet the entry criterion (Tabachnick & Fidell, 1983). The independent variables were: gestational age at birth, visual orientation scores (1, 2, 3, 4, 5), and neurological status (normal, suspicious, abnormal). The descriptive values for the analysis are shown on Table 8. Neurological status at 18 months corrected age was the most significant variable associated with eye-hand performance at 12 months corrected age ($p= 0.00$). It accounted for 32% of the variance in eye-hand developmental quotients. In the second step gestational age at birth was entered as significantly correlated with eye-hand performance at 12 months ($p= 0.05$), and it accounted for an extra 4% of the variance in the dependent variable (R^2[2nd Step]=

0.36). Visual orientation scores at 40 weeks PCA failed to contribute significantly to the equation after the entrance of the first two independent variables (p= 0.42).

TABLE 7

Eye-Hand Developmental Quotients According to Gestational Age Groups

CHARACTERISTIC	MEAN EYE-HAND QUOTIENT	t VALUE (unpaired)	p VALUE (2-tail)
GESTATIONAL AGE GROUP		-3.73	0.0004
<32 WEEKS (n= 34)	108.73 (SD: 21.47)		
32-36 WEEKS (n= 39)	122.79 (SD: 9.08)		

SD: Standard Deviation

TABLE 8

Stepwise Multiple Regression Analysis on Explanatory Variables for Eye-Hand Performance at 12 months (n = 73)

VARIABLE ENTERED	EXPLANATORY VARIABLE	R^2††	MULTIPLE R	F	pVALUE (2- tail)
STEP 1	NEUROLOGICAL STATUS	0.32	0.56	33.20	0.001
STEP 2	GESTATIONAL AGE	0.03	0.60	3.96†	0.05†

†= F test and level of significance referent to the independent variable before entering the equation.
R^2††= Multiple Correlation Squared (the total variance in eye-hand quotients accounted for by each of the explanatory variable before entering the equation).

CHARACTERISTICS OF THE NEUROLOGICALLY NORMAL GROUP OF PRETERM INFANTS

Because neurological outcome was found to be strongly correlated with eye-hand performance at 12 months the same statistical analyses were conducted using only those infants who were diagnosed as neurologically normal at 18 months corrected age (n=45). This procedure enabled the investigation of the possible impact that gestational age and visual orientation may have on eye-hand performance at 12 months, without the influence of poor neurological outcome (abnormal, suspicious).

The neurological outcome for the entire cohort of infants was described earlier in this chapter on Table 3 (p. 37). Of the 73 infants in the study sample 45 (61.64%) were assessed as being neurologically normal at 18 months corrected age. Of the 45 neurologically normal infants at 18 months corrected age, 18 (40%) were born at < 32 weeks PCA and 27 (60%) were born 32-36 weeks PCA. The frequencies of gender, gestational age at birth and birthweight for the 45 normal infants are described in Table 7.

The frequencies of the visual orientation scores for the 45 normals infants, as assessed with the Neurological Assessment of the Preterm and Fullterm Newborn Infant (Dubowitz & Dubowitz, 1981) at 40 weeks PCA, are illustrated in Figure 5. As can be seen the overall pattern of scores is the same as was found with the entire cohort. The visual orientation scores were classified into the two categories: "non-optimal" (scores 1 and 2; n=10), and "optimal" (scores 3, 4, and 5; n=35). Refer to the Methods section (p. 29) for the rationale for these criteria.

TABLE 9

Frequencies of Gender, Gestational Age, and Birthweight for the Neurologically Normal Infants, by Gestational Age Group

CHARACTERISTIC	GESTATIONAL AGE GROUP			
	<32 WEEKS (n=18)		32-36 WEEKS (n=27)	
GENDER				
MALE	10	(55.56%)	14	(51.85%)
FEMALE	8	(44.44%)	13	(48.15%)
GESTATIONAL AGE				
25-27 WEEKS	5	(27.78%)	-	
28-29 WEEKS	8	(44.44%)	-	
30-31 WEEKS	5	(27.78%)	-	
32-33 WEEKS	-		13	(48.15%)
34-36 WEEKS	-		14	(51.85%)
BIRTHWEIGHT				
< 750 gm	1	(5.56%)	-	
750-1000 gm	5	(27.78%)	-	
1001-1500 gm	8	(44.44%)	1	(3.70%)
1501-2500 gm	4	(22.22%)	24	(88.89%)
> 2500 gm	-		2	(7.41%)

INFERENTIAL ANALYSES

I. Comparison of G.A. groups on Visual Orientation at 40 weeks PCA

The two gestational age groups of neurologically normal infants were compared on their visual orientation scores at 40 weeks PCA by first performing a Chi-Square analysis as previously described. The observed frequencies of visual orientation did not significantly differ from the expected frequencies (p= 0.7144; with continuity correction applied). The findings are reported in Table 8 and Figure 6.

TABLE 10

Comparison of Gestational Age Groups by Visual Orientation Categories for the Neurologically Normal Infants (X^2= 0.13; p=0.714; df=1†)

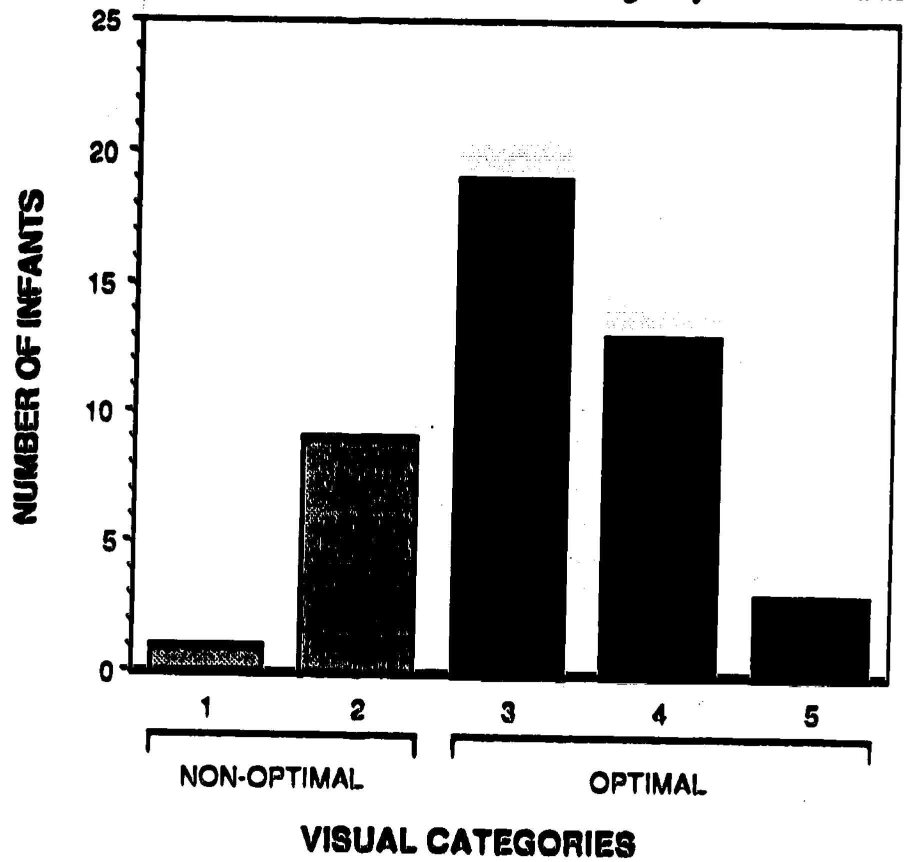
VISUAL ORIENTATION CATEGORIES	GESTATIONAL AGE GROUPS <32 WEEKS (n=18)		32-36WEEKS (n=27)	
OBSERVED FREQUENCIES				
OPTIMAL	13	(72.22%)	22	(81.48%)
NON-OPTIMAL	5	(27.78%)	5	(18.52%)
EXPECTED FREQUENCIES				
OPTIMAL	14	(77.78%)	21	(77.78%)
NON-OPTIMAL	4	(22.22%)	6	(22.22%)

†df= degrees of freedom

To compare the two gestational age groups of neurologically normal preterm infants (<32 weeks; 32-36 weeks) on the actual scores obtained on the visual orientation item (1, 2, 3, 4, or 5), a Mann-Whitney U test was conducted. No significant difference between the two gestational age groups on visual orientation scores was found (p=0.115; U=175). The results are reported in Table 11.

FIGURE 5

Frequency of Visual Orientation Scores for the Neurologically Normal Infants



Legend for Visual Orientation Scores:

1= The infant does not focus or follow stimulus

2= Stills; focus on stimulus; may follow 30° jerkily; does not find stimulus again spontaneously

3= Follows 30-60° horizontally; may lose stimulus but finds it again. Brief vertical glance

4= Follows with eyes and head horizontally and to some extent vertically with frowning

5= Sustained fixation; follows vertically, horizontally, and in circle.

FIGURE 6

Observed Frequencies of Visual Orientation at 40 weeks PCA According to Gestational Age for the Neurologically Normal Infants

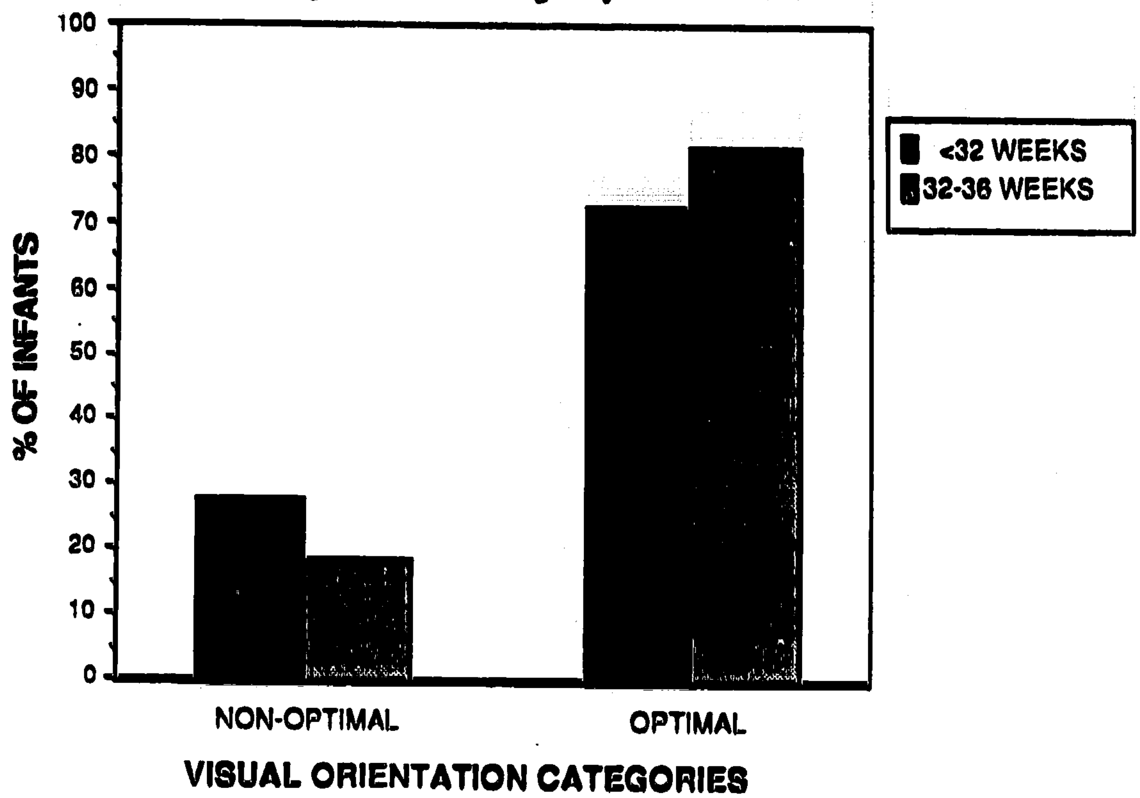


TABLE 11

Frequencies of Visual Orientation Scores According to Gestational Age Groups for the Neurologically Normal Infants (z=-1.58; p=0.115)

VISUAL SCORES	GESTATIONAL AGE GROUP	
	<32 WEEKS (n=18)	32-36 WEEKS (n=27)
1	-	1 (3.70%)
2	5 (27.80%)	4 (14.80%)
3	10 (55.60%)	9 (33.30%)
4	2 (11.10%)	11 (40.70%)
5	1 (5.60%)	2 (7.40%)

II. Comparison of Optimal/Non-Optimal Visual Orientation Categories (40 weeks PCA) on Eye-Hand Performance at 12 months

Ten of the 45 neurologically normal infants (22.22%) had scores of 1 or 2 (non-optimal visual orientation), and 35 of the 45 normal infants (77.78%) had scores of 3, 4, or 5 (optimal visual orientation). See Figure 5. An unpaired t-test was conducted to compare the "optimal" infants with the "non-optimal" infants, on eye-hand performance at 12 months corrected age. The results revealed that infants who had "non-optimal" visual orientation at 40 weeks post-conception had significantly higher eye-hand quotients at 12 months corrected age than infants who had "optimal" visual orientation (p= 0.015; df=43). The results are reported in Figure 7 and Table 12.

TABLE 12

Eye-Hand Developmental Quotients According to Visual Orientation Categories for the Neurologically Normal Infants

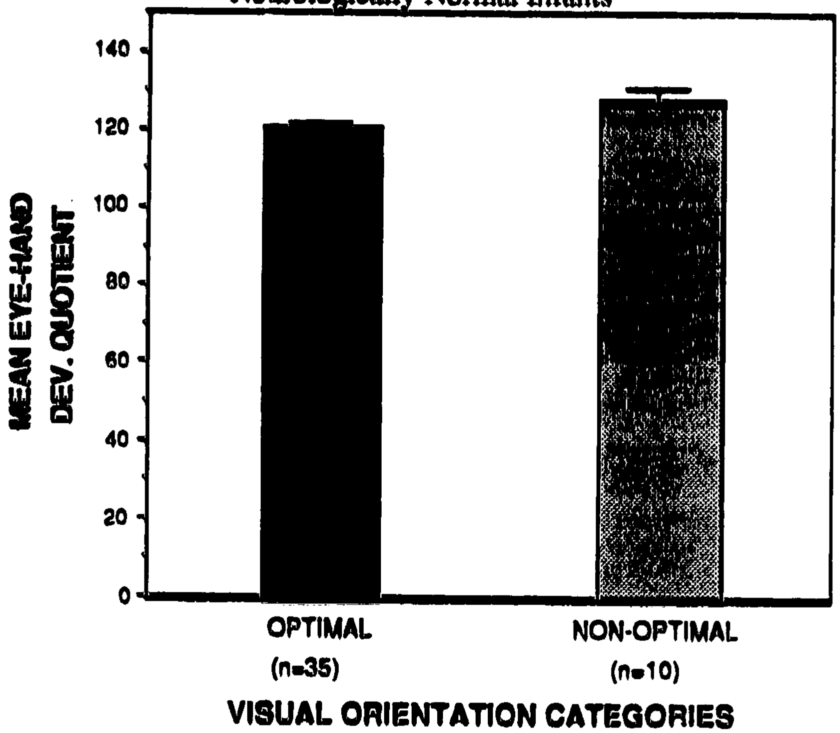
CHARACTERISTIC	MEAN EYE-HAND QUOTIENT	t VALUE (unpaired)	p VALUE (2-tail)
VISUAL ORIENTATION		2.53	0.015
OPTIMAL (n=35)	120.32 (SD: 8.24)		
NON-OPTIMAL (n=10)	127.96 (SD: 8.99)		

SD: Standard Deviation

Jaspen's M coefficient of multiserial correlation was calculated to compare the actual visual orientation scores at 40 weeks (1, 2, 3, 4, and 5) with eye-hand developmental quotients at 12 months corrected age, for the 45 normal infants. The calculated coefficient was r(M)= -0.28, revealing that visual orientation scores at 40 weeks PCA were negatively correlated with eye-hand developmental quotients at 12 months corrected age (p=0.06), although the strength of this association was poor. The scattergram in Figure 8 shows a negative tendency in the relationship between visual orientation scores at 40 weeks PCA and eye-hand performance at 12 months corrected age. This relationship approached significance levels (p= 0.06).

FIGURE 7

Eye-Hand Developmental Quotients According to Visual Orientation Categories for the Neurologically Normal Infants



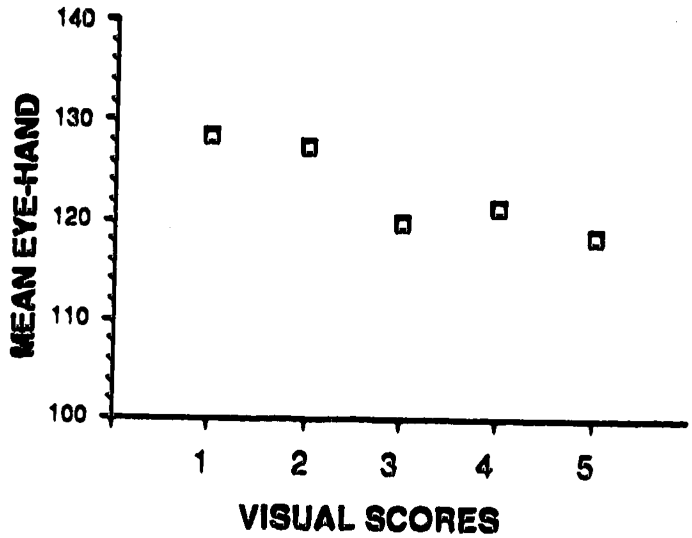
Error bars= 1 standard error of the mean

III. Difference Between Gestational Age Groups on Eye-Hand Performance at 12 months

With the group of neurologically normal infants an unpaired t-test was conducted to examine whether the two gestational age groups (<32 weeks; 32-36 weeks) differ on the eye-hand performance at 12 months corrected age. The findings fail to show a statistically significant difference between the two gestational age groups on the eye-hand developmental quotients for the neurologically normal group of infants (p= 0.09; df=43). The descriptive results are reported in Table 13.

FIGURE 8

Mean Eye-Hand Developmental Quotients by Visual Orientation Scores for the Neurologically Normal Infants



IV. Stepwise Multiple Regression Analysis for Eye-Hand Performance at 12 months

A stepwise multiple regression analysis was performed to determine which variable or combination of variables were associated with eye-hand performance at 12 months, for the normal group of infants. The independent variables were: gestational age at birth, and visual orientation scores (1, 2, 3, 4, 5). Neither of them reached significance. The descriptive values are shown on Table 14.

TABLE 13

Eye-Hand Developmental Quotients According to Gestational Age Groups for the Neurologically Normal Infants

CHARACTERISTIC VALUE	MEAN EYE-HAND QUOTIENT	t VALUE	p (2-tail)
GESTATIONAL AGE GROUPS		-.1.73	0.09
<32 WEEKS (n= 18)	119.27 (SD: 9.79)		
32-36 WEEKS (n=27)	123.85 (SD: 7.93)		

SD: Standard Deviation

TABLE 14

Stepwise Multiple Regression Analysis on Explanatory Variables for Eye-Hand Performance at 12 months for the Neurologically Normal Infants (n=45)

VARIABLE ENTERED	EXPLANATORY VARIABLE	R^2††	MULTIPLE R	F	p VALUE (2-tail)
STEP 1	VISUAL ORIENTATION	0.07	0.28	3.64	0.06
STEP 2	GESTATIONAL AGE	0.04	0.35	2.32†	0.13†

†= F test and level of significance referent to the independent variable before entering the equation.
R^2††= Multiple Correlation Squared (the total variance in eye-hand quotients accounted for by each of the explanatory variables before entering the equation).

CHAPTER V

DISCUSSION

This study had three major objectives. First, it aimed to evaluate the impact of gestational age at birth and the subsequent extrauterine environment on visual orientation at 40 weeks post-conceptional age (PCA). Second, it examined the relationships between preterm infants' visual orientation at 40 weeks PCA with eye-hand performance at 12 months corrected age, and between gestational age at birth with eye-hand performance at one year of age. Finally, it studied the association of gestational age at birth, visual orientation at 40 weeks PCA, and neurological status at 18 months corrected age with eye-hand performance at 12 months corrected age. These objectives were examined in two groups of infants: 1) the entire cohort of preterm infants (n=73), and 2) a sub-group of preterm infants who were diagnosed as neurologically normal at 18 months corrected age (n=45).

The results of this study demonstrated that the frequency of poor neurological outcome is higher among preterm infants born at younger gestational ages than among infants born at older gestational ages. Thus, as presented in Table 3 (p. 37), 47% of the infants born at <32 weeks gestation had a neurologically suspicious or abnormal outcome, compared with 31% of infants born between 32-36 weeks gestational age. Because of the strong association between gestational age at birth and neurological outcome, it is difficult to assess the impact of preterm birth on infants' visual orientation or eye-hand performance without taking into account neurological outcome.

When considering the entire cohort (N= 73), infants born at <32 weeks gestation showed significantly poorer visual orientation and lower eye-hand quotients than infants born 32-36 weeks gestation. When the neurologically normal preterm infants (N=45) were considered as a separate group, these results were not confirmed.

Rather, the two gestational age groups of normal preterm infants (<32 weeks gestation; 32-36 weeks gestation) did not differ significantly on either visual orientation at term or eye-hand performance at 12 months corrected age. Consequently, it is possible to conclude that the lower performance demonstrated by the preterm infants born at younger gestational ages may be more strongly attributed to their poor neurological status than to early birth itself. Thus, in an attempt to eliminate the effect of neurological status, the analyses were performed with the group of neurologically normal preterm infants (n= 45). The following discussion addresses only this group.

When considering the neurologically normal group of infants, the results revealed three major findings: 1) gestational age at birth did not impact on preterm infants' visual orientation at 40 weeks PCA; 2) gestational age at birth did not impact on eye-hand performance at 12 months corrected age; and 3) visual orientation at 40 weeks PCA was negatively correlated with eye-hand performance at 12 months corrected age.

This study failed to show a relationship between gestational age at birth and visual orientation at 40 weeks PCA. This particular finding is in disagreement with those studies that found the prolonged extrauterine environment experienced by young preterm infants to have a negative impact on early visual processing (Ferrari et al., 1983; Morante et al., 1982). It is also in disagreement with the investigators who contend that extrauterine experience has a positive impact on early visual processing (Baraldi et al., 1981; Kopp et al., 1975). Rather, this finding suggests that early visual orientation is not affected by gestational age at birth, among neurologically normal preterm infants and consequently, prolonged extrauterine experience neither enhances nor retards preterm infants' visual orientation at term. This finding is in agreement with that reported by Parmelee (1975). He found no consistent evidence to support the suggestion that the development of preterm infants may be either advanced or retarded by prolonged exposure to extrauterine environment. According to Allen & Capute (1986b) and Parmelee (1975), prolonged extrauterine experience does not have a measurable effect on visual responses such as preferential looking, visually evoked potentials, habituation to light, and optokinetic nystagmus. The present study suggests that prolonged extrauterine experience may also not have a measurable effect on visual orientation at 40 weeks PCA among neurologically normal preterm infants.

The second major finding from this study revealed that gestational age at birth is not significantly related to later eye-hand performance among normal preterm children. In fact, in the current study all preterm infants with normal neurological status performed within expected age ranges on the eye-hand subscale of the Griffiths assessment. This finding supports the theory of development of Gesell (1933) and Saint-Anne Dargassies (1966) that development is biologically driven, regardless of the environmental experience. According to this theory infants should have similar developmental outcomes, when examined at the same age post conception, regardless of their gestational age at birth. However, contrary to both this theory and the results reported in this study, a number of other researchers have shown poorer performance among preterm infants, especially in the area of fine motor development, and have attributed their findings to the difference in gestational age. Piper et al. (in press) observed both gross and fine motor performance of two gestational age groups of preterm infants at eight and 12 months of age and found that infants born at younger gestational ages showed poorer fine motor performance than infants born at older gestational ages.

Other investigators have reported similar delays in fine motor development when comparing preterm with full-term infants. Field et al. (1981) followed a group of preterm infants with respiratory distress syndrome. At 8 months corrected age they reported poorer performance on items requiring fine-motor abilities by the preterm group when compared with full-term and post-term infants. Ross (1985) and Forslund & Bjerre (1985) reported similar results. According to Ross (1985), at 12 months corrected age the preterm group was less likely to succeed on items involving eye-hand coordination, imitation, and vocalization. Forslund & Bjerre (1985) also observed a delayed performance on fine motor development among preterm infants, when compared with full-terms, at 18 months of age. Two major differences between these investigations and the present study may serve to explain the discrepancies in the reported results. First, while none of them had controlled for neurological disorders among the preterm infants, this present study examined a group of neurologically normal infants separate from the entire cohort. In fact, neurological disorders may have accounted for the delayed performance on fine motor development among preterm infants that was observed by those earlier investigators. The second difference relates to the fact that the studies by Field et al. (1981), Forslund & Bjerre (1985) and Ross (1985) compared the development of preterm with that of full-term infants, while the present study examined two groups of preterm infants born at different gestational ages. Some investigators argue that preterm infants are a unique group with specific patterns of development and, therefore, their performance should not be compared with that of full-term infants (Aylward, 1981; Paludetto et al., 1984; Sigman & Beckwith, 1980).

Besides being in disagreement with studies that compared preterm with full-term infants, the findings from this study also differ from those of studies that compared two different gestational age groups of preterm infants. Piper et al. (in press) in a study that assessed many of the same normal infants reported here, examined the gross and fine motor performance of two groups of preterm infants born at different gestational ages. Even when correction for prematurity was performed, infants born at younger gestational ages showed a significantly poorer fine motor performance than infants born at older gestational ages. In the present study, while the performance of the two gestational age groups was not significantly different, infants born at <32 weeks PCA consistently demonstrated lower eye-hand quotients than infants born between 32-36 weeks PCA. The discrepancies in the results from the two studies may be attributed to the small sample size. Because the results here approached significance, it is possible that a larger sample size might have shown a significant difference between the two gestational age groups on the eye-hand performance at 12 months corrected age, or might have served to reassure the finding reported in the present study.

The third major finding from this study suggested that the visual orientation of neurologically normal preterm infants at 40 weeks PCA was negatively related to eye-hand performance at 12 months corrected age. Although all neurologically normal preterm infants performed within the normal range in the eye-hand assessment at 12 months corrected age, those who had "optimal" visual orientation at 40 weeks PCA obtained significantly lower eye-hand quotients at 12 months than the preterm infants who had "non-optimal" visual orientation. When examining the correlation between the actual visual orientation scores (e.g. 1, 2, 3, 4, 5) and later eye-hand quotients, the relationship was found to be negative but it was neither strong ($r_M = -0.28$) nor statistically significant ($p = 0.06$). These two statistical analyses examined the data from two different perspectives. The correlation analysis correlated the visual orientation <u>scores</u> obtained by the preterm infants at 40 weeks PCA with their eye-hand quotients at 12 months corrected age. The t-test analy...s used the visual orientation <u>categories</u> and tested whether the group of infants who had an "optimal" visual orientation at 40 weeks PCA differed from the group that had a "non-optimal" visual orientation, on their eye-hand quotients at 12 months. The criteria used to define the two visual orientation categories may explain the difference found between analyses. "Optimal" visual orientation included the scores of 3, 4 and 5. The score of 3 was the mode response among the preterm infants (Figures 1 and 5); consequently, it seemed appropriate to consider the visual orientation evidenced by the majority of subjects as being "optimal". The scores of 1 and 2 were then considered as being "non-optimal" responses. Although we cannot ignore that the eye-hand performance of the normal infants who had an "optimal" response was significantly different from the eye-hand performance of those who had a "non-optimal" response, the criterion used to allocate the infants into the "optimal" and "non-optimal" categories was somewhat arbitrary and as such may not have been the best way of analyzing the visual orientation scores. It might be concluded that the correlation analysis, using actual scores rather than categories of function, produced more meaningful results regarding the early visual orientation and later eye-hand performance of normal preterm infants.

The correlation between early visual orientation scores and later eye-hand quotients did approach significance and, although it was not strong, it did show a trend towards a negative relationship between these two variables. This is an unexpected finding. There are two methodological issues that may have influenced this finding: 1) the assessment tools used to measure both visual orientation at 40 weeks PCA and eye-hand performance at 12 months of age may not be valid measures of these two functions; and 2) during the 12 month period between the assessments of visual orientation and eye-hand performance, the infants were not monitored on possible environmental stimulation that may have contributed to the relationship found between these variables.

In the present study, the assessment tool used to measure eye-hand performance at 12 months corrected age was not a specific measure of visual motor behavior. Rather, at 12 months, the eye-hand subscale from the Griffiths Mental Developmental Scale basically measures whether the infant can hold a pencil and use it on paper (see Table 15). Such items do not specifically require infants' visual attentiveness during the motor behavior. Furthermore, this scale has a pass/fail scoring criteria and does not evaluate the quality of the response given by the infant. It may be as possible for a visually impaired child to pass items such as "can hold a pencil" and "use it on paper" as it is for a child with normal visual abilities. In this case, a more specific assessment may have provided more valid information regarding the relationship between visual and fine motor abilities. The items from the fine motor scale of the Peabody Developmental Motor Scales (Folio & Fewell, 1983) are examples of tasks involving visual motor behavior. Such items require the child to open a box and remove candy pellets, turn pages from a book, build a tower with four cubes, etc. These items appear to require greater integration of visual motor skills. In addition the Peabody Developmental Fine Motor Scales have a larger number of items involving visual motor skills, and this may give more valid index of fine motor function. Consequently, the fine motor scale of the Peabody Developmental Motor Scales may be a more accurate measure of infants' eye-hand performance than the eye-hand subscale from the Griffiths Mental Developmental Scale, as it focuses more on infants' visual motor abilities.

In addition to the limitations addressed in relation to the measure of eye-hand performance, the measure of visual orientation itself is subject to criticism. This study used only one item from a multiple item assessment tool and compared the response from this item with outcome at 12 months. It is possible and likely that the visual orientation item from the Neurological Assessment of the Preterm and Full-term Newborn Infant (Dubowitz & Dubowitz, 1981) was not meant to stand by itself as an early indication of later eye-hand performance of preterm infants. Taken by itself, the visual orientation item has a subjective scoring criteria. It relies on the examiner's judgement to decide whether the infant followed 30° jerkily (score of 2) or followed 30-60° horizontally (score of 3). While the reliability of this item has not been reported, the authors of the original neurological assessment noted that the entire tool has shown good inter-observer coefficients (Dubowitz & Dubowitz, 1981). It is known that the reliability of an assessment tool does not guarantee the same stability of its separate individual items (Brazelton, 1984).

Investigators have used visual orientation responses to document the development of visual function among preterm (Dubowitz, 1979) and full-term infants (Brazelton, 1984), up to 40 weeks PCA. The visual orientation of preterm infants has also been compared with the visual orientation of full-term infants, both at 40 weeks PCA (Ferrari et al., 1983; Forslund & Bjerre, 1983). Most investigators argue that visual orientation responses in newborn infants are good indicators of early visual functioning as well as of neurological maturity (Brazelton, 1966; Brazelton, 1984; Dubowitz, 1979). These studies differ from the present study in terms of methodology

TABLE 15

Items from the Eye and Hand Subscale of the Griffiths Mental Developmental Scale

MONTHS OF AGE	ITEM DESCRIPTION
10	-Plays pulling ring or toy by string Throws objects.
11	-Thumb opposition complete; Can point with index finger.
12	-Interested in motor-car; Can hold pencil as if to mark on paper; Uses pencil on paper a little.
13	-Likes holding little toys; Preference for one hand.
14	-Plays rolling ball; Can hold 4 cubes in hands at once.

employed. While the earlier studies specifically examined the visual orientation responses of infants as a single item assessment, the present study extracted one item from a general neurological procedure. It is possible that the items of the neurological examination which were tested prior to the visual orientation item may have interfered with the visual response given by the infant. By using one item from an entire battery of items, to measure infants' visual orientation at 40 weeks PCA, this study may not have validly assessed the actual visual orientation status of the preterm infants, thereby, accounting for the negative relationship between early visual orientation and later eye-hand performance. While earlier studies have used this visual orientation item to describe the visual functioning of preterm and full-term infants (Brazelton, 1966; Dubowitz, 1979), the visual orientation as tested here may only be a good indicator of early function rather than a predictor of later more complex visual motor skills such as those required in eye-hand coordination. Future studies employing more appropriate measures of visual orientation and eye-hand performance should be conducted in order to better evaluate the relationship between these variables.

The fact that the two measurements were performed 12 months apart and that the infants were not monitored for possible stimulation (environment, treatment), may also have contributed to the negative relationship between infants' visual orientation (assessed at 40 weeks PCA) and eye-hand performance (assessed at 12 months corrected age). It is possible that parents of the infants who received lower scores on visual orientation may have become aware of their children's poor visual abilities and provided appropriate play activities which served to enhance their eye-hand or fine motor skills. Consequently, environmental stimulation, which was not held as a constant variable, might have influenced the findings from this study. This explanation is in agreement with that provided by Sigman & Beckwith (1980). Their study examined the correlation between preterm and full-term infants' visual fixation at term with developmental outcome at two years of age, as measured by the Bayley Mental Scale. In the preterm group there was a negative relationship between amount of early visual fixation and the developmental outcome recorded at two years. According to the authors, one factor that may have accounted for the negative relationship reported was the two year period between the two measures. Indeed, prospective studies that look for early predictors of later developmental outcome should account for the possible environmental stimulation that infants receive from their caregivers, as it might influence developmental outcome.

The negative relationship found between early visual orientation and later eye-hand performance was attributed to two methodological limitations of this study. Although it is possible that environmental stimulation might have interfered with later eye-hand performance more strongly than early visual orientation, it is also likely that the negative relationship is explained by the inaccuracy of the assessment tools used. Indeed, neither of these two limitations can fully account for the negative relationship reported in this study. Rather, it is probable that these two methodological issues may have combined together to produce this unexpected finding. Future investigation is needed to describe the actual relationship between early visual orientation and later eye-hand performance.

In summary, in agreement with other investigations, the findings from this study indicated that poor neurological outcome interferes with preterm infants' developmental outcome at a further point in time. Furthermore, gestational age at birth did not impact on early visual orientation or on later eye-hand performance, among neurologically normal preterm infants. Finally, the study reported a negative relationship between visual orientation at 40 weeks PCA and eye-hand performance at 12 months corrected age. This final finding is partially explained by methodological flaws. Further research in this area is recommended.

CHAPTER V

SUMMARY AND CONCLUSIONS

The findings of this study suggested that neurological outcome strongly impacts on preterm infants' developmental performance. Indeed, the results of the analyses performed with the entire cohort of infants differed considerably from the results of the analyses performed with only the neurologically normal preterm infants. Consequently, when examining the impact of preterm birth, per se, on infants' developmental performance, neurological outcome should be taken into consideration.

No significant relationship was found between gestational age at birth and visual orientation at 40 weeks PCA. This finding supports the premise that the amount of extrauterine experience neither enhances nor retards the development of visual skills such as the ability to focus on and follow a visual stimulus. The results also fail to demonstrate a significant relationship between gestational age at birth and later eye-hand performance. Furthermore, this study reported a negative relationship between early visual orientation and later eye-hand performance. This negative relationship was partially attributed to the inadequate measures of early visual orientation and later eye-hand performance of preterm infants. Besides using more accurate instruments it is suggested that future studies also monitor the environment that infants experience, in an attempt to control for the stimulation that infants may have received during the 12 month period between the first and second evaluations.

Significance of the Study

Studies examining the development of preterm infants have reported some delays in fine-motor development, particularly in those abilities involving visual-motor functions (Klein et al., 1985; Piper et al., in press; Ungerer & Sigman, 1983). The current study aimed to investigate possible predictors of later eye-hand performance in preterm infants. Specifically, the findings from this study provided significant information regarding the impact of gestational age at birth on visual orientation at 40 weeks PCA, and on the association between visual orientation at 40 weeks PCA with eye-hand performance at 12 months corrected age. These findings have relevance for therapists who work in early intervention programs with preterm infants, since they address factors that may or may not influence later development.

The findings in this study suggest that young gestational age at birth and the subsequent extrauterine environment experience neither retard nor enhance visual orienting or eye-hand performance of neurologically normal preterm infants. According to this finding, for neurologically normal preterm infants, gestational age at birth does not impact on either their ability to focus on a stimulus and to track it in different directions, at 40 weeks PCA, or on their eye-hand performance at 12 months corrected age. It implies that prolonged extrauterine environment, which provided visual experience as well as motor activity to normal young preterm infants is not harmful to their performance, when they were compared to their older counterparters. Also, the findings from this study do not provide evidence to support the premise that early experience enhances normal young preterm infants' visual orientation or eye-hand performance. If these data are replicated by future research, the therapeutic practice of environmental intervention for neurologically normal preterm infants must be strongly questioned. Also, intervention programs aiming to improve fine motor performance among normal young preterm infants should be reviewed.

When neurological outcome was not taken into account, the findings of this study showed that younger preterm infants had poorer visual orientation and poorer eye-hand performance than the older group. As most early intervention programs are directed towards the neurologically suspicious and abnormal infants, the role of the therapists' intervention with this group of infants should be further investigated. Indeed, therapists have been evaluating the efficacy of early intervention programs in an attempt to justify their practice (Anderson, 1986; Case-Smith, 1988; Leib et al., 1980). Leib et al. (1980) and Case-Smith (1988) contend that early intervention methods involving sensory stimulation produce improved developmental outcomes for high-risk preterm infants. The results of these studies suggest that there may well be a role for therapists working with infants who are likely to have a suspicious or abnormal neurological outcome. Consequently, neurological outcome may be used as an indicator for defining the group of preterm infants who should receive early intervention programs.

A common limitation among the studies that examine the developmental performance of preterm infants refers to the fact that most assessment tools are normed on the performance of full-term infants. Consequently, the preterm population may be mistakenly described as having either enhanced or retarded performance when measured with these assessment tools. The present study reinforces the need for the development of assessment tools normed among preterm infants. It is critical that valid measures be developed in order to properly document the development of preterm infants. Only by using measurement tools which appropriately measure the developmental functioning of preterm infants, will it be possible to study the true relationship between the variables considered in the present study.

Future Directions

The results of this study reveal that neurological outcome is strongly associated with developmental performance of preterm infants. In order to study the impact of preterm birth on later developmental outcome, it is important to distinguish preterm birth from the medical complications associated with young gestational age at birth. As such, this study suggests that future investigators consider examining the development of neurologically normal preterm infants as one group and the neurologically suspicious and abnormals as a separate group. This study demonstrates that neurologically normal preterm infants born within two different gestational age groups did not differ significantly on either visual orientation at birth or on later eye-hand performance. Further investigation is required to determine how infants born at varying gestational ages are affected on their fine-motor development. It is also recommended that future studies that prospectively examine the impact of preterm birth on infants' developmental outcome consider monitoring the environment that the infant experiences. Finally, this study stresses the need for the development of assessment tools which have been normed on preterm infants, rather than full-terms.

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APPENDICES

APPENDIX A

Informed Consent Form†
(Preterm Infants)

I have been told that the objective of this study is to evaluate the effect of premature birth on early motor development. I have been informed that information will be taken from my child's birth and hospital records and that my child's motor development will be evaluated several times during his hospital stay. In addition, I understand that my child's motor development will be evaluated six times during his first year of life and once again during his second year of life. All assessments will be observational in nature and will not involve any equipment or invasive techniques.

I have been assured that no information which could influence my decision to allow my child to participate has been withheld from me. There have been no restrictions on the questions I have wanted to ask to better understand the nature of the study. I have also been assured that my decision to give or withhold my consent will in no way affect the other treatments or services my child receives.

I am aware that I am free to withdraw my consent and to discontinue my child's participation in the research project at any time.

NAME:______________________________
(please print)

DATE:______________________________

SIGNATURE: _________________________

WITNESS:___________________________

† From the study entitled: "Impact of preterm birth on the neuromotor development of the premature infant" by Dr. M.C. Piper & Dr. P. Byrne

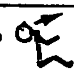
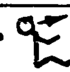
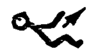
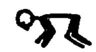
APPENDIX B

The Neurological Assessment of The Preterm and Fullterm Newborn Infant

NAME		D.O.B./TIME	WEIGHT	E.D.D. L.N.M.P.	E.D.D. U/snd.
HOSP.	NO.	DATE OF EXAM	HEIGHT		
RACE	SEX	AGE	HEAD CIRC.	GESTATIONAL ASSESSMENT	SCORE WEEKS

STATES
1. Deep sleep, no movement, regular breathing.
2. Light sleep, eyes shut, some movement.
3. Dozing, eyes opening and closing.
4. Awake, eyes open, minimal movement.
5. Wide awake, vigorous movement.
6. Crying.

						STATE	COMMENT	ASYMMETRY
HABITUATION (≤state 3)								
LIGHT Repetitive flashlight stimuli (10) with 5 sec. gap. Shutdown = 2 consecutive negative responses	No response	A. Blink response to first stimulus only. B. Tonic blink response. C. Variable response.	A. Shutdown of movement but blink persists 2-5 stimuli. B. Complete shutdown 2-5 stimuli.	A. Shutdown of movement but blink persists 6-10 stimuli. B. Complete shutdown 6-10 stimuli.	A. Equal response to 10 stimuli. B. Infant comes to fully alert state. C. Startles + major responses throughout.			
RATTLE Repetitive stimuli (10) with 5 sec. gap.	No response	A. Slight movement to first stimulus. B. Variable response.	Startle or movement 2-5 stimuli, then shutdown	Startle or movement 6-10 stimuli, then shutdown	A. B. C. – Grading as above			
MOVEMENT & TONE	Undress infant							
POSTURE (At rest – predominant)			(hips abducted)	(hips adducted)	Abnormal postures: A. Opisthotonus. B. Unusual leg extension. C. Asymm. tonic neck reflex			
ARM RECOIL Infant supine. Take both hands, extend parallel to the body; hold approx. 2 secs. and release.	No flexion within 5 sec.	Partial flexion at elbow >100° within 4-5 sec.	Arms flex at elbow to <100° within 2-3 sec.	Sudden jerky flexion at elbow immediately after release to <60°	Difficult to extend; arm snaps back forcefully			
ARM TRACTION Infant supine; head midline; grasp wrist, slowly pull arm to vertical. Angle of arm scored and resistance noted at moment infant is initially lifted off and watched until shoulder off mattress. Do other arm.	Arm remains fully extended	Weak flexion maintained only momentarily	Arm flexed at elbow to 140° and maintained 5 sec.	Arm flexed at approx. 100° and maintained	Strong flexion of arm <100° and maintained			
LEG RECOIL First flex hips for 5 secs, then extend both legs of infant by traction on ankles; hold down on the bed for 2 secs. and release.	No flexion within 5 sec.	Incomplete flexion of hips within 5 sec.	Complete flexion within 5 sec.	Instantaneous complete flexion	Legs cannot be extended; snap back forcefully			
LEG TRACTION Infant supine. Grasp leg near ankle and slowly pull toward vertical until buttocks 1-2" off. Note resistance at knee and score angle. Do other leg.	No flexion	Partial flexion, rapidly lost	Knee flexion 140-160° and maintained	Knee flexion 100-140° and maintained	Strong resistance; flexion <100°			
POPLITEAL ANGLE Infant supine. Approximate knee and thigh to abdomen; extend leg by gentle pressure with index finger behind ankle.	180-160°	150-140°	130-120°	110-80°	<80°			

HEAD CONTROL (post. neck m.) Grasp infant by shoulders and raise to sitting position; allow head to fall forward; wait 30 sec.	No attempt to raise head 	Unsuccessful attempt to raise head upright 	Head raised smoothly to upright in 30 sec. but not maintained. 	Head raised smoothly to upright in 30 sec. and maintained 	Head cannot be flexed forward 			
HEAD CONTROL (ant. neck m.) Allow head to fall backward as you hold shoulders; wait 30 secs.	Grading as above 	Grading as above 	Grading as above 	Grading as above 				
HEAD LAG * Pull infant toward sitting posture by traction on both wrists. Also note arm flexion.								
VENTRAL SUSPENSION * Hold infant in ventral suspension; observe curvature of back, flexion of limbs and relation of head to trunk.								
HEAD RAISING IN PRONE POSITION Infant in prone position with head in midline.	No response	Rolls head to one side	Weak effort to raise head and turns raised head to one side	Infant lifts head, nose and chin off	Strong prolonged lifting			
ARM RELEASE IN PRONE POSITION Head in midline. Infant in prone position; arms extended alongside body with palms up.	No effort	Some effort and wriggling	Flexion effort but neither wrist brought to nipple level	One or both wrists brought at least to nipple level without excessive body movement	Strong body movement with both wrists brought to face, or 'press-ups'			
SPONTANEOUS BODY MOVEMENT during examination (supine). If no spont. movement try to induce by cutaneous stimulation.	None or minimal Induced	A. Sluggish. B. Random, incoordinated. C. Mainly stretching.	Smooth movements alternating with random, stretching, athetoid or jerky	Smooth alternating movements of arms and legs with medium speed and intensity	Mainly: A. Jerky movement. B. Athetoid movement. C. Other abnormal movement.	1 2		
TREMORS Mark: Fast (>6/sec.) or Slow (<6/sec.)	No tremor	Tremors only in state 5-6	Tremors only in sleep or after Moro and startles	Some tremors in state 4	Tremulousness in all states			
STARTLES	No startles	Startles to sudden noise, Moro, bang on table only	Occasional spontaneous startle	2-5 spontaneous startles	6+ spontaneous startles			
ABNORMAL MOVEMENT OR POSTURE	No abnormal movement	A. Hands clenched but open intermittently. B. Hands do not open with Moro.	A. Some mouthing movement. B. Intermittent adducted thumb	A. Persistently adducted thumb. B. Hands clenched all the time.	A. Continuous mouthing movement. B. Convulsive movements.			