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DETERMINANTS OF ATTENTION IN PREMATURE INFANTS

by

Judith Gardner

A dissertation submitted to the Graduate Faculty in Psychology in partial fulfillment of the requirements for the degree of Doctor of Philosophy, The City University of New York.

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ABSTRACT

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This study investigated whether the level of arousal of premature infants influences their visual preferences.

Neonates' looking responses have been found to be related to quantitative dimensions of stimulation such as brightness, number of angles, number of elements, contour density and temporal frequency. When presented with quantitatively varying stimuli, infants look longest at stimuli of intermediate values.

Schneirla (1965) has suggested that this response to quantitative aspects of stimulation is determined by the effective intensity of stimulation, and thus is a function of the nature of both the stimulus and the organism on which it impinges. Karmel and Maisel (1975) have suggested that visual preferences are related to the amount of neural activity resulting from stimulation in relation to spontaneous background level of activity. Schneirla's hypothesis would suggest that the amount of neural activation produced may be a function not only of the stimulus, but of the characteristics of the organism as well. Shifts in preference might then result from shifting arousal levels such that there would be an inverse relationship between the level of arousal of the infant and the intensity of the stimulus. To the extent that they affected arousal, swaddling and feeding would thus be expected to influence preferences.

To explore this possibility, 32 prematurely born infants were tested when awake and non-crying for visual preferences when they were

37 to 40 weeks postconception. Infants were tested twice before and once after feeding on two successive days. On the second day, they were swaddled during the postfeeding and the second of the prefeeding tests. Each test session involved the presentation of three ordered pairs of stimuli two times (with position reversed) for 30 sec. Sixteen infants were shown varying sizes and numbers of cubes (i.e., one 2 in. cube, four 1 in. cubes, sixteen 1/2 in. cubes, and a blank card of equivalent luminance). The other 16 infants were shown varying frequencies of illumination (i.e., .5, 1, 2, and 4 Hz; with durations of 1000, 500, 250, and 125 msec, respectively). Duration of fixation of each of the stimuli was recorded by an observer. Infants' heart rate was recorded to obtain an independent measure of arousal level.

The results indicated that the distribution of attention in premature infants was influenced by their internal condition. Changes in feeding and swaddling condition resulted in changes in the stimuli preferentially attended. The proportion of time spent looking at the more intense stimulus increased from the most aroused (unswaddled prefeeding) to the least aroused (swaddled postfeeding) condition, $F(2,30)=4.88$, $p < .02$; $F(2,30)=12.47$, $p < .01$; for cube stimuli and frequency stimuli, ANOVAs. Although the amount of looking did not differ with condition, infants showed consistent increases in differential looking as arousal was reduced, with each pair of stimuli showing the same regular relationship. Heart rate also changed with feeding and swaddling condition, with lowest rates occurring swaddled postfeeding and highest rates unswaddled prefeeding, $p < .001$, Friedman test.

The distribution of visual attention in premature infants is therefore influenced by state. To the extent that feeding and swaddling resulted in increased looking at more intense stimuli by lowering arousal, the finding of an inverse relationship between level of arousal of the infant and objective intensity of a stimulus support the view that preferential looking is determined by the amount of neural activation independent of the manner in which it is achieved.

In addition, some infants were presented with additional pairs of stimuli to complete a paired comparisons design. These pairs were presented during the postfeeding test sessions so as not to interfere with feeding schedules or test conditions. The relationship between amount of looking to each of the stimuli and the magnitude of stimulus intensity yielded linear trends with the highest intensity stimulus being most preferred for both the cube and the frequency stimuli.

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CHAPTER I

INTRODUCTION

The purpose of this research was to determine whether the level of arousal of premature infants influences the nature of the visual stimuli to which they are preferentially responsive, and whether changes in arousal can modify these preferences.

Premature infants are a population at risk for poor developmental outcome, especially since recent medical progress has greatly increased the survival rate of very-low-birthweight and very immature infants (Kopelman, 1978; Rush, Keirse, Howat, Baum, Anderson and Turnbull, 1976). Although the incidence of substantial neurological defects appears to be decreasing (Davies and Tizard, 1975; Fitzhardinge and Ramsey, 1973; Rawlings, Reynolds, Stewart and Strang, 1971; Stewart, Turcan and Rawlings, 1977), there appears to be an increased incidence of cognitive and perceptual dysfunction in those infants who survive (DeHirsch, Jansky and Langford, 1966; Drillien, 1972; Lubchenko, Delivoria-Papadopoulos and Searls, 1972; Wiener, Rider, Oppel and Harper, 1968; Siegel, Siagal, Rosenbaum, Young, Berenbaum and Stoskopf, Note 1). Because the likelihood of later problems is higher in premature than in full-term infants, and is even more prevalent in surviving very-low-birthweight infants, it is important to identify atypical aspects of their functioning which may provide clues as to the possible mechanisms underlying subsequent poor development. This can be done by investigating the features of the environment to which the infant responds and the ways in which changes in the external environment of the infant, as well as changes in his internal organization, can affect responding.

Recent research has shown that infants are highly responsive to visual aspects of their environment, and that the features of the environment to which they are attentive change during the first months of life. Because it affects the stimuli infants are most likely to respond to, and therefore learn about, the absence of appropriate changes in visual attention or the presence of atypical distributions of attention, is of considerable importance for subsequent development. In fact, a number of studies have found that in both older infants and neonates, the amount and distribution of attention as indicated by performance on looking tasks are related to condition at birth.

Lewis, Bartels, Campbell and Goldberg (1967) found that infants with lower Apgar scores at birth differed from those with higher Apgar scores on amount of time spent looking when they were examined at three and at nine to thirteen months. Differences have been found between premature and full-term infants even when matched for conceptional age. Sigman and Parmelee (1974) found differences between premature and full-term infants when they were four months of age in their preference for face-like stimuli and in their preference for novel stimuli after habituation; and Sigman (1976) also found differences in preference for novelty after habituation when the premature and full-term infants were eight months old. Field (1979) found differences between premature and full-term infants at three months of age in their looking behavior to animate and inanimate objects such that the premature infants looked less at stimuli which were more arousing, than full-term infants did.

Stechler (1964) found an association between looking behavior during the neonatal period and condition of the infant as indicated and influenced by maternal medication during labor, and Sigman, Kopp, Parmelee and Jeffrey (1973) found an association in neonates between visual attentiveness and condition at birth as assessed by a neurological examination.

In addition, differences between premature and full-term infants when they are 40 weeks post conceptional age have been found with regard to visual attentiveness (Sigman, Kopp, Littman and Parmelee, 1977) and visual orienting behavior (Kurtzberg, Vaughan, Daum, Grellong, Albin and Rotkin, in press).

More long term predictive relationships between early looking behavior and subsequent cognitive functioning are suggested by differences between infants with Down's syndrome and normal infants (Miranda, 1976) in the age at which certain preferences appear. Fantz and Nevis (1967) also found a relationship between age of appearance of visual preferences and scores on the Griffiths Mental Development Scale. Fagan (Note 2) has reported a high correlation between visual memory at four to seven months, defined as preferential visual fixation to novel stimuli, and later intelligence at 3.8 to 6.5 years, defined by performance on standard vocabulary tests. Although details concerning the basis for the judgments are not available, judgments of the overall functioning of premature infants on tests of visual preferences were found to predict their functioning on Stanford-

Binet or Bayley Scales at ages ranging from 15 to 60 months more accurately than did a pediatric evaluation (Miranda, 1976).

Atypical patterns of visual attention during early infancy may not only predict but also contribute to later deficiencies because they may result in attending to aspects of the environment which do not adequately promote cognitive development. In addition, responding to unusual aspects of the environment may result in further changes in what is responded to, causing an ever growing divergence from typical patterns of development.

Since Fantz's (1958) pioneering work on visual preferences in infants, differential looking has been used to identify aspects of the visual world which are discriminable and salient for the human infant. Investigators have found that when very young infants are shown pairs of figures that differ in size, brightness, number of angles, rate of change of illumination, contour length or contour density, they do not look at them for equivalent amounts of time. These studies indicate that for many of the aspects of stimuli thus identified, the neonate's responses are determined by quantitative aspects of the stimuli. For example, when degree of complexity is manipulated, infants look longest at stimuli of intermediate values with progressive decreases in looking to stimuli that diverge further and further from what is considered an optimal level (Greenberg and Blue, 1975). Similarly, when infants are presented with figures having more or fewer angles, preference gradients around an optimal level are found (Hershenson, Munsinger and Kessen, 1965). Similar quantitative optimal level gradients have been obtained for brightness

(Hershenson, 1964), number of elements (Fantz and Fagan, 1975), contour density (Karmel, 1969), and temporal change (Karmel, Lester, McCarvill, Brown and Hofmann, 1977).

Although the basis for this preferential looking has not been established it is possible that the amount of stimulation provided by the various stimuli is, in each case, determining responsiveness. That is, when size, brightness, number of angles, etc. are varied, the amount of stimulation provided is also being varied. For example, two stimuli identical with respect to all features except amount of contour would differ with regard to amount of neural activity which they elicited. Such differences in stimulative properties could be the basis for the differential attractiveness of stimuli. It should be noted that discussion of the amount of stimulation provided by an object in the baby's world refers to the effective intensity of the stimulus as defined by Schneirla (1965), and not merely its objective characteristics. Thus, the same object can be a weak or a strong stimulus depending on such factors as the condition of the receptor and condition of the organism. Furthermore, as previously indicated, intensity is not being restricted to brightness as is sometimes done, but is instead considered a general characteristic of stimuli which can be varied in many ways.

Some investigators have attributed preferences to qualitative aspects of stimuli, e.g. pattern configuration (Fantz and Nevis, 1967). However, the data thus far available suggest that such qualitative aspects of visual stimuli do not become important determiners of preferential looking until infants are about two months of age. Prior to two months, the effective intensity of a stimulus, as determined by characteristics of both the organism and the environment, appears to be the important determinant of responding.

McCarvill and Karmel (1976) found that differences in luminance affected visual preferences in younger (nine week old) but not older (13 week old) infants. Maisel and Karmel (1978) found that, regardless of the orientation of the lines or the configuration, responding was based on the amount of contour and the size of the stimulus in younger but not older infants. In five to six week old infants, the latency and duration of look were affected by stimulus size when the amount of contour was equated, and the latency to look was affected by size when contour density was equated. However, in eight to ten week old infants, none of these effects of size were found. Ruff and Turkewitz (1975) found that when infants were shown pairs of stimuli consisting of a bullseye and a horizontally striped pattern of different sizes, the older infants (12 weeks and over) looked more at the bullseye regardless of its size or the size of the striped pattern paired with it. Younger infants (six and nine week olds), on the other hand, looked longer at the larger of the pair of stimuli independently of its pattern. That older infants attend to stimuli in terms of qualitative features such as pattern, whereas younger infants are more attentive to quantitative aspects is further supported by the finding that differences in brightness affect preferential looking in a manner similar to that of size (Ruff and Turkewitz, 1979).

In addition, Ruff and Turkewitz's results provided some support for the hypothesis that visual attention in young infants is determined by stimulation, independently of the manner in which it is achieved. Thus, when both brightness and size were varied, their effects summated to produce bigger preferences than were produced by size or brightness alone. This finding suggests the possibility that size and brightness both affect a common dimension (intensity) which in turn determines visual attention. Similar additive effects of different stimulus attributes in determining effective intensity were obtained by McGuire and Turkewitz (1978) who found that the finger movements of young infants were determined by the combined effects of size, distance and brightness of a rotating cone.

Responding by young infants on the basis of quantitative aspects of stimulation has recently been shown with stimulation of two different modalities. Lewkowicz (1979), using a habituation-dishabituation paradigm, repeatedly presented three week old infants with a light of a fixed intensity and then measured cardiac change to sounds of different intensities. He found a U-shaped dishabituation gradient with the least cardiac change to a sound in the middle of the range presented, and greater and greater cardiac change as the sound diverged from this value. This was interpreted as indicating that the infants were treating the visual and auditory stimuli as equivalent; that is, the infants were responsive to the stimuli in terms of similarities in their intensities rather than to the qualitative differences between them. When adults were tested using the same procedure, they gave no evidence of an intensity based intersensory equivalence.

Because there is evidence suggesting that young infants respond to stimuli in terms of their effective intensity, and because the effective intensity of a stimulus is a function not only of the stimulus but also of the organism on which it impinges, it seems likely that changes or differences in the characteristics of the organism result in changes or differences in preferential looking. So, for example, changes or differences in level of dark adaptation, level of arousal, or maturity would all be expected to systematically affect preferential looking. According to this conception, there is a level of stimulation for maintaining maximum attention and a gradient around it; however, there might be different optimal levels for different infants.

Evidence exists indicating that changes in visual preferences occur with changes in the age of infants. For example, although both younger and older infants are responsive to number of elements, older infants prefer figures with more elements, whereas younger infants tend to prefer figures with fewer elements (Brennan, Ames and Moore, 1966; Fantz and Fagan, 1975). A shift to preference for greater amounts of contour density with increasing age has been found with both checkerboard-like stimuli (Karmel, 1969, 1974; McCarvill and Karmel, 1976), and with a variety of pattern configurations (Maisel and Karmel, 1978). Hoffmann (1978), investigating the physiological basis for the observed changes in preference behavior, recorded visual evoked potentials from different scalp locations. He found changes in the amplitude of several components of the visual evoked potential as a function of changes in the amount of contour. The effect on the components at different locations was related to the age of the infants, and there was a close correspondence between the behavioral preferences at six and ten weeks of age and the maximum amplitudes of different components to different amounts of contour.

Further evidence of a relationship between neural maturation and visual preferences has been obtained in a number of investigations of preference behavior in premature infants. It has been found that premature infants do not exhibit the same pattern of preferences that full-term infants do. Miranda (1970) found differences in the preference behavior of premature and full-term infants when he presented checkerboard-like stimuli in which size and number of elements varied. The premature infants appeared to prefer one large square over four smaller ones while the full-term infants preferred four smaller squares to one larger one. However, Jones-Molfese (1972) found differences between premature and full-term infants on this task only when three-dimensional stimuli were used. In addition, although both full-term and premature infants have been found to be more responsive to size than to number of elements, this dominance is found to a greater extent in premature than in full-term infants (Miranda, 1976). Karmel (1969) attributed differences in preferential looking behavior to activity levels of cells in the visual system which change as the baby matures. Thus, differences in preference may be dependent upon difference in background levels of neural activity of premature and full-term infants. Karmel has found a relationship between spatial frequency (amount of contour density), temporal frequency (rate of change of illumination), amount of neural activity (as determined by visual evoked potentials) and visual preferences (Karmel and Maisel, 1975).

Because events which increase or decrease the effective intensity of stimuli may alter visual attention, shifts in preference might result not only from differing maturational levels of the nervous system, but from shifting arousal levels of the infant as well. Variability in the distribution of attention to the same objective stimuli may therefore be a consequence of fluctuating internal states. Although it is well known that responses will differ with differing levels of receptor adaptation (e.g. brightness thresholds with whether the eyes are light or dark adapted), changes in preferences in relation to changes in the internal state of an organism have not been well studied.

No direct evidence concerning the relationship between arousal level and visual preference has been reported. Evidence does exist, however, for a relationship between state and responsiveness to stimulation. For example, differences in response to auditory (Ashton, 1973; Berg, Berg and Graham, 1971; Campos and Brackbill, 1973; Hutt, Lenard and Prechtl, 1969; Korner, 1972; Pomerleau-Malcuit and Clifton, 1973; Schulman, 1970), tactile (Lewis, Bartels and Goldberg, 1967; Pomerleau-Malcuit and Clifton, 1973) and vestibular (Pomerleau-Malcuit and Clifton, 1973) stimulation have been found to be related to the infant's state of arousal as measured by cardiac rate. A relationship between state and visual attentiveness has also been reported (Giacoman, 1971; Korner, 1972). In addition, although the findings tend to be inconsistent, a number of investigators have found differences in evoked potentials to stimulation when infants were in different sleep states and therefore had different background EEG's (Akiyama, Schulte, Schultz and Parmelee, 1969; Barnet and Goodwin, 1965; Ellingson, 1958; Hrbek, Hrbkova and Lenard, 1969; Monod and Garma, 1971; Weitzman, Fishbein and Graziani, 1965; Weitzman and Graziani, 1968).

Inasmuch as infants' levels of arousal are related to their feeding states, it is possible that there are differences in their preferences before and after feeding. To the extent that they affect arousal, external manipulations such as swaddling or patting the infant, or turning on lights or sounds, could also result in changes in the infants' visual preferences.

Both feeding and swaddling have, in fact, been shown to affect the level of arousal of the infant. Korner (1972) found that prandial condition affected many of the behaviors used to differentiate the various levels of arousal. For example, she reported increases in activity, crying, and number of shifts in state, and decreases in sleep before feeding as compared to after feeding. Lipton, Steinschneider and Richmond (1965) found similar effects due to swaddling condition. However, Giacoman (1971) found that, although both feeding and swaddling reduced crying, only swaddling prior to feeding increased sleep.

There has, moreover, been some investigation of the level of arousal of the infant, as influenced by feeding and swaddling, as a factor contributing to effective intensity, and therefore to responsivity. Korner (1972) reported that infants were more responsive to auditory stimuli after feeding, and Giacoman (1971) found that infants were more attentive to visual stimuli after feeding and that this effect was enhanced if they were both swaddled and fed. Turkewitz, Fleischer, Moreau, Birch and Levy (1966) found changes in directional finger movements as a function of feeding condition. The infant's arousal level, as determined by prandial condition, has also been found to influence the effective intensity of auditory stimuli. Thus, when the infant is more aroused (before feeding), he turns his eyes in the direction of the same auditory stimulus which is ineffective when he is less aroused (after feeding) (Turkewitz, Birch, Moreau, Levy and Cornwell, 1966). Similarly, it has been found that the same tactile stimulus is more effective in eliciting head turns before than after feeding (Prechtl, 1958; Turkewitz, Gordon and Birch, 1965).

In addition to the various behavioral measures indicating that feeding and swaddling affect the level of arousal of an infant, it has also been shown that both feeding and swaddling lower the arousal level as measured by heart rate. Although heart rate has been shown to be a useful measure of state, it should be noted that infants at the same level of arousal as indicated by heart rate may be at different levels when measured by activity and vice versa (Bridger and Reiser, 1959). However, this does not necessarily imply that heart rate is an unreliable measure of state, as it has been found to reflect level of autonomic activity when individual differences in the relationship between cardiac activity and behavioral activity are taken into account (Bridger, Birns and Blank, 1965). The differences among neonates in prestimulus heart rate variability when behavioral state is controlled, have also been found to be related to cardiac responsiveness to stimulation (Porges, Arnold and Forbes, 1973).

Although heart rate responses to stimulation are affected by both the modality and intensity of the stimulus, in general, the effect of stimulation is inversely related to the resting heart rate level. That is, when the prestimulus rate is relatively low, an increase in rate is seen to stimulation and when the prestimulus rate is relatively high, a decrease to stimulation is seen. This is an instance of what has been referred to as the Law of Initial Values (Bridger and Reiser, 1959) and has been used to explain the variability in heart rate responding among infants having different prestimulus levels and to explain differences in responding when infants are in different states.

Clifton (1978) has reviewed the effects of state and feeding and sucking on heart rate. She found differential effects of stimulation in relation to sucking activity which are not just due to increased motor activity. She has also found that differential responding depended on whether the infant was at the beginning or end of a waking period. She interpreted the finding (Malcuit-Pomerleau and Clifton, 1973) that after feeding the heart rate tended to increase to stimulation whereas prior to feeding the rate tended to decrease to the same stimulation as due to infants being at the beginning of a wakeful period prior to feeding and toward the end of a wakeful period (becoming drowsy) after feeding. Alternative explanations are possible. However, regardless of the reason for the different arousal levels before and after feeding, it is apparent that the effective intensity of stimulation will differ as a result of it.

The effects of motor restraint by swaddling on heart rate has been investigated by Lipton et al. (1965). They found that the prestimulus heart rate was lower when the infant was swaddled, and that this effect was not just due to reduced motor activity or to tactile stimulation. They also found an inverse relationship between the infant's state of arousal, as indicated by his mean prestimulus heart rate, and his responsivity to tactile stimulation.

In summary, there is evidence that very young infants' differential responsivity to visual stimuli is determined by the effective intensity of the stimuli, which is a function of both stimulus characteristics and characteristics of the infant. In addition, there is evidence that characteristics of the infant such as level of maturity of the nervous system and state affect responsivity to stimulation, Differences in preferential looking may thus be related both to maturation of the nervous system and also to more transient changes such as changes in arousal level. If, in fact, visual preferences are affected by state of arousal, it should be possible to change preferences by changing the level of arousal of the infant. The present study was designed to investigate this question by examining which stimuli prematurely born infants look at before and after feeding and when they are unswaddled or swaddled. It was hypothesized that they would prefer stimuli of higher intensities when they are less aroused (postfeeding and/or swaddled) than when more aroused (prefeeding and/or unswaddled). Premature infants were selected for study because it was believed that findings obtained with them would be useful in understanding visual preference behavior of young infants in general and because findings from this study might provide a basis for development of a useful diagnostic tool for the identification of deviant infants.

CHAPTER II

Study 1 - The relationship between level of arousal and preferential looking at stimuli varying in size and number of elements.

Method

Subjects

The subjects were 19 prematurely born infants (11 males and 8 females) who were resident in the Intensive Care Unit of Jacobi Hospital of the Bronx Municipal Hospital Center. All infants were from either Black or Hispanic families. Prematurity was defined as being born at or below 37 weeks estimated gestational age (EGA).[1] Gestational age was estimated by the Dubowitz method (Dubowitz, Dubowitz and Goldberg, 1970) which is based on the assessment of 10 neurological and 11 physical characteristics. The infants varied with regard to their age at birth, the basis for the prematurity, and the medical procedures they received while on the Unit. However, at testing, all infants were over 2100 gms, had been deemed medically stable by the pediatric staff, and were ready for hospital discharge. The data from 3 of the 19 infants (2 males and 1 female) were eliminated because the infants did not stay awake through all conditions of the study. Table 1 shows the EGA at birth, birthweight, postconceptional age and postnatal

1. The normal length of gestation in humans is 40 weeks.

Table 1

Characteristics of the Infants Studied with Stimuli

Varying in Size and Number of Elements

	EGA[a]	Birthweight (grams)	PCA[b]	PNA[c]	Sex
	28	900	39.0	11.0	F
	31	990	40.5	9.5	F
	32	1400	37.0	5.0	F
	32	1500	37.0	5.0	F
	32	1350	37.5	5.5	M
	33	1680	37.0	4.0	M
	34	2570	36.0	2.0	M
	34	1970	37.0	3.0	M
	34	1660	38.0	4.0	M
	34	1380	40.0	6.0	M
	34	1420	40.0	6.0	M
	35	1560	39.5	4.5	F
	36	2905	37.5	1.5	M
	36	1840	39.0	3.0	F
	37	2050	38.5	1.5	F
	37	1630	39.5	2.5	M
$\bar{X}$	33.7	1675	38.3	4.6	
SD	2.4	517	1.4	2.7	

<u>Note.</u> All ages are given in weeks.

[a] Estimated gestational age at birth

[b] Postconceptional age at testing

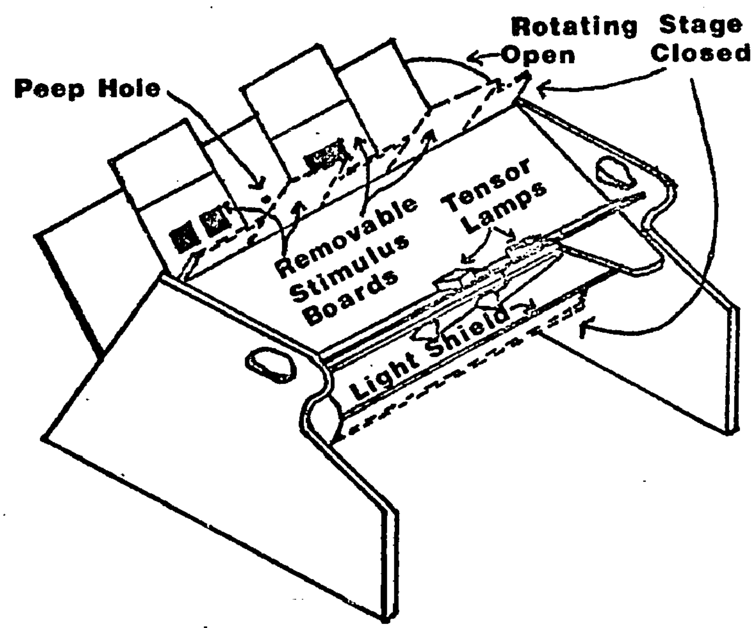
[c] Postnatal age at testing

age at the time of testing, and sex for each infant whose data were included in the study.

Apparatus and Stimuli

The visual preference apparatus was modeled after one described by Fagan (1970) and Fantz and Nevis (1977) (see Fig. 1). It consisted of a three-sided chamber with a pivotal stage used for controlled stimultaneous presentations of paired stimuli. The inside of the chamber was lined with medium grey felt to reduce glare and to provide a contrasting background against which the black and white stimuli stood out distinctly. Stimuli were mounted on 6 x 11 3/4 in. (15.2 x 29.8 cm) boards which were covered with matching felt and held in place by magnets. When the stage was rotated open between trials, the boards could be easily changed and accurately positioned. The bottom of the stage projected at a 90° angle from it. Thus, the observer who changed the stimuli between trials was effectively hidden from the infant by upward rotation of the bottom of the stage. When the stage was closed, the stimuli were exposed to the infant's view. The infant's eye movements could be observed through a 1/4 in. (.64 cm) peephole located in the center of the stage. Two miniature

Figure 1. Essential details of the visual preference apparatus. Redrawn from Fagan (1970).



Peep Hole
Rotating Stage
Open
Closed
Removable
Stimulus
Boards
Tensor
Lamps
Light Shield

low-voltage tensor lamps (Sylvania bulb No. 55), mounted on the roof of the chamber and shileded from the baby's view, illuminated the stimuli. The number and duration of fixations to each of the stimuli were recorded on a Rustrak event recorder. One channel was used to record looking to the right and a second channel was used to record looking to the left. A third channel was used to mark the onset of a trial.

The stimuli were wooden cubes painted flat black affixed to white backgrounds (cards that measured 6 x 6 in. (15.2 x 15.2 cm). They were chosen for their saliency and were patterned after those used by Jones-Molfese (1972). They consisted of one 2 in. (5.1 cm) cube, four 1 in. (2.5 cm) cubes, and sixteen 1/2 in. (1.3 cm) cubes. The cubes were positioned in the center of the cards such that the distance between them was the same as the size of one side of the cube. In addition, a minimal intensity unpatterned white stimulus card was included. All stimuli were closely matched in luminance. This luminance level was approximately 6.1 ft L. The unpatterned stimulus was made equivalent in luminance to the stimulus with which it was paired through the use of a rheostat which attenuated the light from the appropriate tensor lamp. However, because the rheostat worked by reducing the amount of energy to the bulb, its use caused changes in hue in addition to the brightness changes. To overcome this problem, the last nine infants were tested by placing a .3 log neutral density filter in front of the appropriate lamp to equate for luminance between the unpatterned stimulus and the stimulus with which it was paired.

Procedure

All infants were tested in a room in the Neonatal Intensive Care Unit. Because looking behavior can be examined only in quiet, alert infants (State 3 or 4 of the Prechtl scale; Prechtl, 1965), certain variations were incorporated into the procedure to maximize the maintenance of infants in this state. Depending on the infants' behavior, they were tested while seated in a semi-reclining position either on the lap of an assistant or in a padded infant seat with diapers as additional padding to stabilize their heads. Five infants were held on the lap of an assistant during testing, six infants were tested while seated in the infant seat, and five infants were seated in the infant seat during some sessions and held on the lap during others. Thus, the infant was between 14 and 17 in. (35 and 44 cm) from the near edge of the stimulus. In addition, a number of tactics were used to maintain the State 3 or 4 condition between trials. These included pacifiers, talking, patting, stroking, rocking, etc. as needed. If none of these worked, testing was interrupted briefly or completed at another time.

Each test session involved the presentation of three pairs of stimuli: 0 and 1 cubes, 1 and 4 cubes, and 4 and 16 cubes, two times (with position reversed) for a total of six trials per session. Each trial lasted 30 sec with an intertrial interval of approximately 30 sec. The trials and intertrial intervals were timed on a stopwatch by an assistant. A trial started when the observer determined that the infant had its eyes open and was properly positioned. All infants received the same random sequence of stimulus pairs. This was done to allow for the systematic evaluation of individual differences.

The infants' fixations were determined by the direction of eye gaze during the stimulus presentations. If there was ambiguity as to the direction of eye gaze, the corneal reflections of the infant were checked for the relative positioning of the stimuli. The direction of gaze was then determined by which stimulus was reflected from the corneal surface over the pupil. Nothing was recorded if the reflections from the two eyes were different, if neither stimulus was reflected from the area of the pupillary opening, or if the reflections could not be determined. There was a criterion of at least 2 secs of looking on each trial. This was determined by reading the event recorder paper immediately after the trial if there was a question about whether the criterion was reached. If the infant did not look for this amount of time because he was crying or his eyes were closed, the trial was repeated. In order for the data from any session to be included for analyses, the infant had to complete all trials within that session.

To examine the hypotheses about the effect of arousal level on preferential looking, the infants were tested under conditions designed to produce variations in state of arousal. Thus, infants were tested within one hour before and one hour after a scheduled feeding, and while they were unswaddled or swaddled. They were tested according to the schedule presented in Table 2.

Table 2

Test No.	Day 1	Test No.	Day 2
1	Prefeeding - Unswaddled	4	Prefeeding - Unswaddled
2	Prefeeding - Unswaddled	5	Prefeeding - Swaddled
3	Postfeeding - Unswaddled	6	Postfeeding - Swaddled

This idealized schedule was departed from as necessitated by the infants' availability for testing while in the appropriate condition. Departures from the above schedule resulted in four babies being tested postfeeding unswaddled on Day 1 and then prefeeding unswaddled, and two babies being tested postfeeding swaddled on Day 2 before they were tested prefeeding unswaddled and prefeeding swaddled.

All testing was done around the midmorning or early afternoon feedings with the exception of two infants who were tested prior to the 6 P.M. feeding. Day 2 testing occurred on the day immediately following Day 1 testing with three exceptions: one infant had one day between the two days, and two infants had five days between testing due to equipment problems.

Reliability

All data in the present investigation were obtained by a single observer. To assess the reliability of the observer's judgment as to the direction of gaze of the infants, two observers (one of whom was the observer in the study) simultaneously observed an infant comparable to the infants in the study. One observer viewed the infant through the centrally located peephole in the rear of the chamber between the two stimuli. The second observer viewed the mirror reflection of the infant through a centrally located peephole in the roof of the viewing chamber. The number and duration of fixations to each of the stimuli in the pairs were independently recorded on separate channels of an event recorder.

The procedures used were equivalent to those in which data were collected by the single observer. The data from eleven trials were used in the assessment of reliability.

The degree of concordance between the two observers was determined by correlating the total amount of looking at each of the stimuli on each trial recorded by the observers. The obtained correlation for looking to the right and looking to the left were each .99.

Results

The data were analyzed with regard to three levels of arousal. The infant was considered to be most aroused when tested before feeding while unswaddled (Tests 1, 2 and 4), least aroused when tested after feeding while swaddled (Test 6), and at some intermediate level of arousal when tested either after feeding while unswaddled (Test 3) or before feeding while swaddled (Test 5). As there was no a priori way to order them relative to each other, the data from these two intermediate conditions were combined.

To determine the relative distribution of attention, the proportion of time spent looking at the stimulus having more elements was calculated relative to the total amount of time spent looking at both members of the pair. The use of proportions normalizes the data for individual variations in total amount of time spent looking at the stimuli. Thus, an infant who looked longer would not contribute disproportionately to the total analysis, and any subject effect would be due to individual differences in what was looked at.

Arousal effects

As can be seen in Fig. 2, the distribution of attention changed with differing states of arousal. The proportion of looking time directed at the stimulus having more elements increased from the most aroused to the least aroused condition. The mean proportion of looking at the stimulus having more elements was .51 for the most aroused condition, .57 for the intermediate condition, and .60 for the least aroused condition. These preferences for stimuli having a greater number of elements were significantly different from chance when the infants were in the intermediate, $t(15)=3.69$, $p < .01$[2], and least aroused, $t(15)=3.43$, $p < .01$, conditions. Analysis of variance indicated that the differences in the distribution of looking in the different arousal conditions were significant, $F(2,30)=4.88$, $p < .02$. Post hoc analyses of these differences using an F-statistic for planned comparisons (Hays, 1973) did not yield any significant differences. Examination of the relationship between looking and level of arousal showed the same regular pattern with each of the three stimulus pairs (see Fig. 3).

2. All analyses were done using a repeated measures design, where appropriate; and all probability levels are for two-tailed distributions.

Figure 2. The proportion of time spent looking at the stimulus having more elements as a function of level of arousal (all pairs combined).

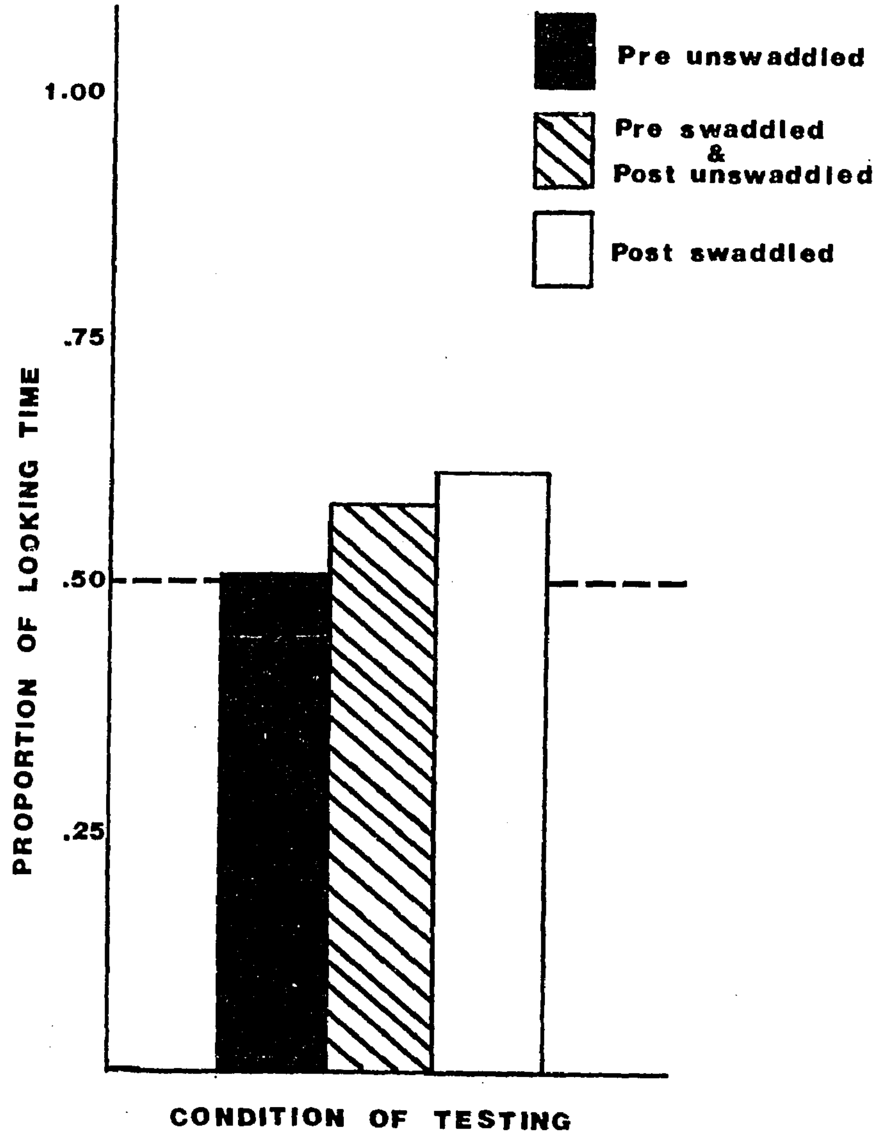
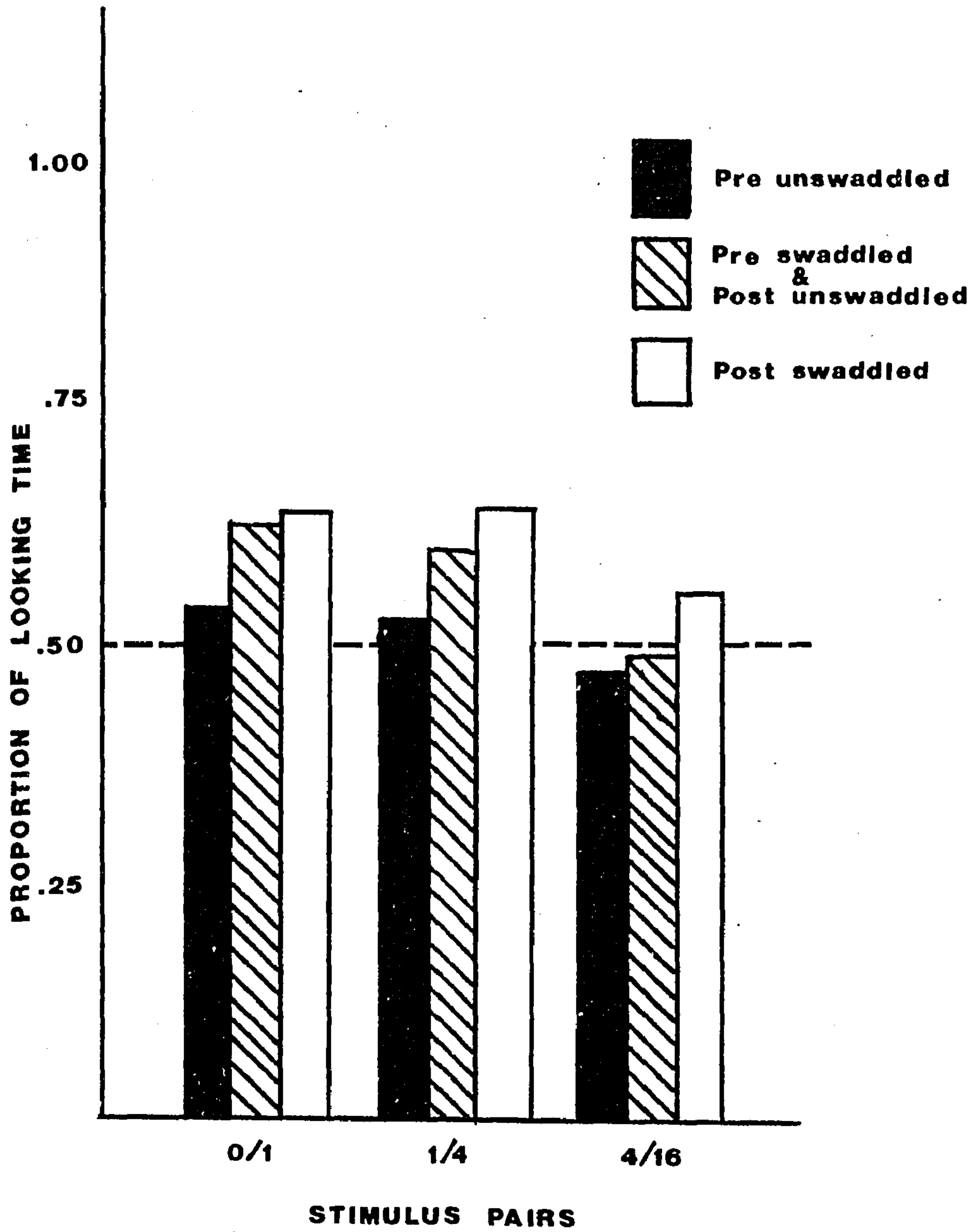

Pre unswaddled
Pre swaddled & Post unswaddled
Post swaddled
1.00
.75
.50
.25
PROPORTION OF LOOKING TIME
CONDITION OF TESTING

Figure 3. The proportion of time spent looking at the stimulus having more elements as a function of level of arousal for each stimulus pair.


1.00
.75
.50
.25
PROPORTION OF LOOKING TIME
Pre unswaddled
Pre swaddled & Post unswaddled
Post swaddled
0/1
1/4
4/16
STIMULUS PAIRS

The infants spent equivalent amounts of time looking at each member of the pair when they were most aroused. This failure to show a preference when most aroused was due to fewer infants showing a preference when in this condition and to those who did show a preference being less consistent in the direction of their preference than when they were less aroused. That is, when preference is defined as the proportion of looking to either member being greater than .54, eight infants showed a preference while in the most aroused condition. Three of these preferred the stimulus with fewer elements. In contrast, 13 infants showed a preference when least aroused, and only one of them preferred the stimulus with fewer elements. A preference was defined as any proportion exceed .54 because there was a gap in the distribution at this level. Despite the arbitrary nature of this decision the effects of this choice are negligable as any criterion from .53 to .56 yields almost identical distributions.

The largest differences in the distribution of looking were between the most and least aroused conditions, i.e. the conditions in which infants were either unswaddled and prior to feeding or swaddled and after feeding. It could not be determined by the initial analyses whether both swaddling and feeding were influencing looking behavior. Therefore, swaddling and feeding effects were analyzed separately by combining the data from all the tests in the unswaddled conditions and comparing them to the combined swaddled conditions (Tests 1, 2, 3 and 4 vs. Tests 5 and 6), and doing the same for the comparison of all the prefeeding conditions to the postfeeding conditions (Tests 1, 2, 4 and 5 vs. Tests 3 and 6). These separate analyses showed both swaddling and feeding to be effective; the effects of swaddling and feeding were significant, $t(15)=2.17$, $p < .05$; $t(15)=2.36$, $p < .02$.

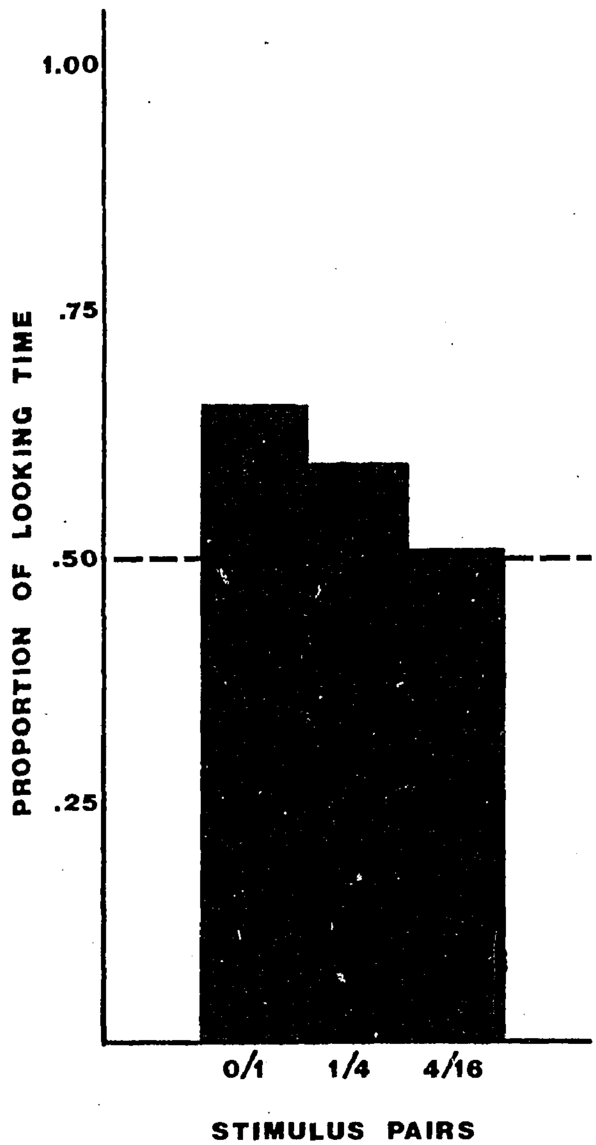
Level of arousal may have affected the proportion of looking by influencing the amount of looking to either or both members of the stimulus pairs. Therefore, to further examine the relationship between preferential looking and arousal, the mean looking time to the stimulus having more elements and the mean looking time to the stimulus having fewer elements were analyzed separately. Analysis of variance yielded a significant main effect of arousal condition for mean looking time to the stimulus with more cubes, $F(2,30)=9.01$, $p < .01$, but the effect of arousal condition on mean looking time to the stimulus with fewer cubes only approached significance, $F(2,30)=2.73$, $p < .10$. Thus, there was an inverse relationship between state and the amount of time infants spent looking at the stimulus with more cubes ($\overline{X}$=20.5, 24.6 and 28.2 sec for the three levels of arousal from most to least aroused, respectively), but no such clear or consistent effect on their looking behavior to the stimulus with fewer cubes ($\overline{X}$=19.4, 19.6 and 18.7 sec for the three levels of arousal from most to least aroused, respectively). Post hoc analyses of the effect of arousal condition on the time spent looking at the stimulus with more cubes by means of planned comparisons yielded significant F-statistics between the most and least aroused conditions, and between the most aroused condition and the other two conditions combined.

Stimulus effects

In addition to the effects of arousal on preferential looking, the effects of the different stimulus pairs were investigated. The proportion of time spent looking at the stimulus with more cubes differed for the three pairs (see Fig. 4), resulting in a significant main effect for stimulus pair $F(2,30)=7.84$, $p<.01$. Infants spent a greater proportion of time looking at the stimulus with more cubes when there were not many cubes in the pairs, i.e. looking at 1 cube in Pair 0/1, and looking at 4 cubes in Pair 1/4, but looked approximately equal amounts of time at each stimulus member when the choice was between 4 and 16 cubes. Post hoc analyses by means of planned comparisons yielded significant F-statistics between Pair 0/1 and Pair 4/16, between Pair 0/1 and Pairs 1/4 and 4/16 combined and between Pair 4/16 and Pairs 0/1 and 1/4 combined.

This effect of particular pairs of stimuli on the proportion of time spent looking was contributed to by both the time the infant spent looking at the member of the pair having more elements and the time the infant spent looking at the member of the pair having fewer elements. Thus, when analyzed separately, there were significant main effects for stimulus pair in the mean amount of looking at both the stimulus member with more cubes and the stimulus member with fewer cubes, $F(2,30)=3.76$, $p<.05$ and $F(2,30)=7.97$, $p<.01$. Although both

Figure 4. The proportion of time spent looking at the stimulus having more elements as a function of stimulus pair (all arousal levels combined).


PROPORTION OF LOOKING TIME
1.00
.75
.50
.25
0/1
1/4
4/16
STIMULUS PAIRS

showed significant results, the pattern of looking was not the same. The amount of time spent looking at the stimulus with fewer cubes increased with increasing overall numbers of cubes in the pairs ($\overline{X}$=16.5, 18.7 and 22.2 sec for Pairs 0/1, 1/4, and 4/16, respectively). The amount of time spent looking at the stimulus with more cubes showed less of a change, with a slight increase and then decrease with increasing numbers of cubes ($\overline{X}$=24.4, 26.4 and 22.6 sec for Pairs 0/1, 1/4, and 4/16, respectively). Post hoc analyses of differences among the pairs in looking at the stimulus with fewer cubes, by means of planned comparisons, yielded significant $\underline{F}$-statistics between Pair 0/1 and Pair 4/16, and between Pair 4/16 and the other two pairs combined. Analyses of differences among the pairs in looking at the stimulus with more cubes did not show any significant differences.

Individual differences

Particularly because premature infants show more variability in responding than do full-term infants (Klatskin, McGarry and Steward, 1966), it is important to consider whether individual babies showed consistency in their responding across conditions. Because all the previously reported analyses used a repeated measures design to control for subject effect, the sums of squares from these analyses were reanalyzed to see whether, in fact, there was a significant main effect for subjects. There was no such subject effect for the proportion of time spent looking at the stimulus with more elements. However, significant subject effects were found in the amount of time spent looking at the stimulus with more elements and in the amount of time spent looking at the stimulus with fewer elements, $F(15,60)=2.92$, $p < .005$; $F(15,60)=3.66$, $p < .001$; respectively. This indicates that the infants showed consistent individual differences in the total amount of time spent looking, but not in the way in which they apportioned their looking. In addition, this indicates that the use of proportions was effective in normalizing these differences in amount of time spent looking, as it was intended to.

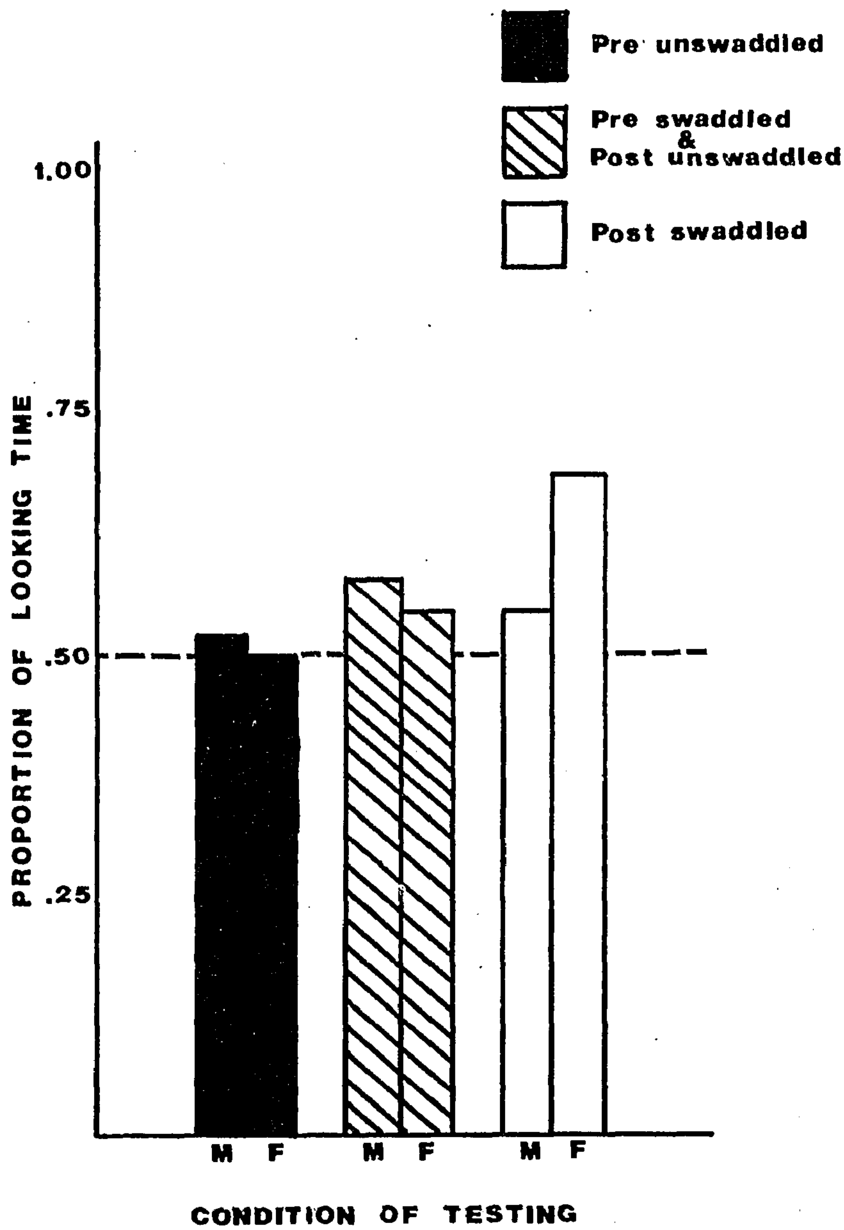
Sex differences

In the present study, no significant main effects for the sex of the infant was found in any of the analyses. With regard to the proportion of time looking at the stimulus with more elements there was, however, a significant arousal level by sex interaction, $F(2,28)=4.70$, $p < .02$. Examination of the data suggests that this interaction was due to the female infants being more susceptible to the treatment effects than were the male infants (see Fig. 5). There were no differences between the male and female infants when they were at the highest and intermediate arousal levels, but there was a significant difference at the lowest level of arousal, $t(14)=2.52$, $p < .02$.

Sequence effects

Because of a desire to examine individual differences, this study was designed using the same schedule of testing for all infants. The exceptions to this schedule are detailed in the Method section. Because the conditions were not randomized across babies, it is possible that any differences obtained among the treatments were, in actuality, due

Figure 5. The proportion of time spent looking at the stimulus having more elements by male and female infants as a function of level of arousal (all pairs combined) (M=male infant, F=female infant).


Pre unswaddled
Pre swaddled & Post unswaddled
Post swaddled
PROPORTION OF LOOKING TIME
1.00
.75
.50
.25
M F
M F
M F
CONDITION OF TESTING

to sequence effects, e.g. habituation or adaptation effects. That is, babies might have increased looking at stimuli with more elements on the second day of testing and on the second or third tests of a day because of their prior exposure to either the stimuli or the testing situation rather than because of differences in conditions during testing.

The sequence of testing was designed to allow the examination of this possibility. Thus, any sequence effects within a testing day can be examined by comparing responses on Tests 1 and 2 which were conducted under identical conditions (prefeeding unswaddled), with one test immediately following the other. Similarly, sequence effects across days can be examined by comparing responses on Tests 1 and 4, which differed only in that Test 4 occurred the day after Test 1, with Tests 2 and 3 intervening between them.

The results indicate that the differences found among the various conditions were not likely to be due to sequence effects. There were no differences in looking prior to feeding while unswaddled on Day 1 and Day 2 (Tests 1 and 4) with respect to any of the measures. There was a difference between Test 1 and Test 2 on Day 1, $\overline{X}$ proportion = .54 and .46, respectively; $\underline{t}(15)=3.31$, $\underline{p}<.05$. However, the direction of this difference, i.e. a decrease in the proportion of looking to the stimulus with more elements, was opposite to that which occurred either after feeding or after swaddling, suggesting that the effect was not mediated by a lowering of arousal consequent upon habituation or adaptation. Any effect of sequence might have been due to the infants becoming more aroused as they got closer to feeding, as indicated by their relative decrease in looking at stimuli with more elements. If such is the case, a random order of testing would have resulted in more not less marked arousal effects.

Attention effects

It is also possible that any differences obtained among the different conditions were due to differences in the amount of attention when infants were in different states. This, however, is not likely. Although the overall amount of looking did increase slightly from the most to least aroused conditions, with infants looking a mean of 19.9, 22.1 and 23.3 sec from the most to least aroused conditions, these differences were not significant.

CHAPTER III

Study 2 - The relationship between level of arousal and preferential looking at stimuli varying in frequency of illumination.

If, as is suggested by the first study, the infant's visual preferences are indeed being influenced by the effective intensity of stimulation as determined by the combination of objective stimulus characteristics and state of the infant, then similar shifts in preference should accompany shifts in state even when very different objective stimulus characteristics are involved.

The frequency with which lights go on and off has been found to be a potent determinant of infant visual attention (Karmel and Maisel, 1975). Therefore, to further investigate the relationship between level of arousal and the nature of the visual stimuli to which premature infants are preferentially responsive, the second study varied temporal frequency rather than spatial frequency. Furthermore, to provide an independent measure of level of arousal, the heart rates of the infants were recorded during the different test conditions. Thus, if infants' heart rates were lower after feeding while swaddled than before feeding while unswaddled, the assumption that feeding and swaddling were acting to reduce arousal levels would be supported.

Method

Subjects

The subjects in the second study were a different group of 17 prematurely born infants (9 males and 8 females) from the same population of infants as those in the first study. The data from one of the 17 babies (a male) were eliminated because he was discharged from the hospital after only an incomplete set of data was obtained on the first day of testing. Table 3 shows the EGA at birth, birthweight, postconceptional age and postnatal age at the time of testing, and sex for each infant whose data wereincluded in this study.

Apparatus and Stimuli

The visual preference apparatus used was the same as that used in Study 1. It was modified, however, to allow for the presentation of the lights. The stage was removed and replaced by a black back panel. The panel had a centrally located 1/4 in. (.64 cm) peephole and two 6 x 6 in. (15.2 x 15.2 cm) cutouts covered by milk glass and mounted in the same postion previously occupied by the cube stimuli. Two wooden boxes affixed to the rear of the panel were used to house photostrobe lamps. The two miniature low-voltage lamps used in the first study were not used. Changes in the frequency of illumination

Table 3

Characteristics of the Infants Studied with Stimuli

Varying in Frequency of Illumination

	EGA[a]	Birthweight (grams)	PCA[b]	PNA[c]	Sex
	31	1530	38.0	7.0	F
	32	1900	37.0	5.0	F
	32	1920	37.5	5.5	F
	33	1585	36.0	3.0	F
	33	1780	36.5	3.5	M
	33	1540	37.0	4.0	F
	33	1600	37.0	4.0	F
	34	1890	36.0	2.0	M
	34	1880	37.0	3.0	M
	34	1900	37.0	3.0	M
	35	1850	37.5	2.5	F
	35	1970	37.5	2.5	M
	36	1860	38.5	2.5	F
	37	1870	38.0	1.0	M
	37	1850	38.5	1.5	M
	37	1860	39.0	2.0	M
$\bar{X}$	34.1	1799	37.4	3.2	
SD	1.9	146	0.9	1.6	

Note. All ages are given in weeks.

[a]Estimated gestational age at birth

[b]Postconceptional age at testing

[c]Postnatal age at testing

were produced by two photostimulators (Grass Model PS2) connected by relays to two waveform and pulse generators (Tektronix Type 162 and Type 161, respectively). This allowed the lights to be presented with equal on and off times so that the total amount of time the lights were on during each trial was the same for all stimuli. The stimuli used had frequencies of .5, 1, 2 and 4 Hz. The duration of on and off time for each stimulus was 100, 500, 250 and 125 msec, respectively. The luminance level was approximately 9.1 ft L. As in the first study, only three of the possible six pairs of stimuli were presented: .5 and 1 Hz, 1 and 2 Hz and 2 and 4 Hz. These frequencies were selected because Karmel et al. (1977) indicated that 14 week old infants showed maximal evoked potentials and attentional responses to stimuli between 4 and 6 Hz. It was thus assumed likely that these much younger babies would prefer stimuli of slower frequencies (i.e., stimuli of about 2 Hz).

A telemetry system (Narco Bio-systems, Transmitter FM-1100-E2, Receiver FM-1100-6) was used to record the infants' heart rate. The signal was sent by the transmitter connected by two surface electrodes on the baby, and was recorded on a tape recorder (Sony Model 252D) which received its input from the FM receiver tuned to the appropriate frequency of the transmitter. A sound associated with the onset and offset of the lights was recorded directly on a second channel of the tape recorder and was used as a stimulus marker.

Procedure

The infants were tested under the same conditions and on the same schedule as that used in the first study. The same basic procedure was also used, with some minor differences. Before testing began, surface electrodes for the recording of heart rate were attached. During testing, all infants were seated on the lap of an assistant except for one infant who was seated in the infant seat during one test session. The distance between the infant and the near edge of the stimuli was between 14 and 17 in. (35 and 44 cm).

A trial started when the observer, who had determined that the infant had its eyes open and was properly positioned, turned on a timer which simultaneously started the lights and activated the event recorder pens. The trial ended after 30 sec when the timer automatically shut off both the lights and the pens of the event recorder. The length of the trial was marked on one of the channels of the event recorder by the activation of the timer. The intertrial interval was not timed but lasted as long as necessary for the observer to reset the stimulus dials to the frequencies to be presented on the next trial and determine that the infant was ready. The minimum amount of time that this took was 25 sec.

Departures from the predetermined schedule of testing resulted in three infants being tested while in the postfeeding unswaddled condition prior to being tested while in the prefeeding and unswaddled conditions on Day 1, and one infant being tested while in the postfeeding swaddled condition on Day 2 prior to being tested while in the prefeeding swaddled conditions.

With the exception of one infant who was tested prior to the 6 P.M. feeding, all testing was done around the midmorning or early afternoon feedings. All testing was done on contiguous days, with the exception of one infant who had three days between the prefeeding tests on Day 2 and the postfeeding test on Day 2, and another infant who had two days between the test days.

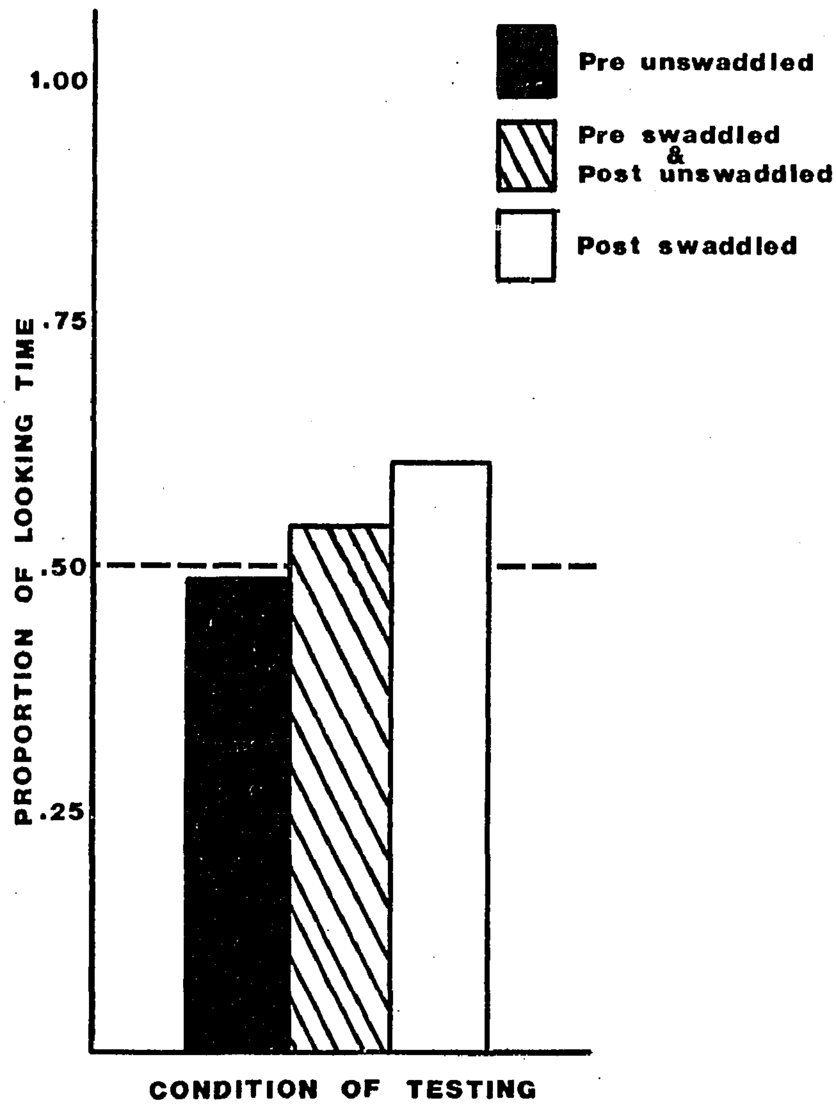
Results

The data were analyzed with regard to the same three levels of arousal as defined in the first study.

Arousal effects

As can be seen in Fig. 6, the distribution of attention changed with differing states of arousal. The proportions of looking time directed at the stimulus having a faster frequency increased from the most aroused to the least aroused condition. Thus, the mean proportions of looking at the stimulus with a faster frequency were .48, .54 and .61 for the most, intermediate and least aroused conditions, respectively. The preference for a faster frequency was significantly different from chance when the infants were least aroused, $t(15)=4.71$, $p<.01$, but not when they were most aroused. The preference for a faster frequency approached but did not reach significance when the infants were at the intermediate level of arousal, $t(15)=1.72$, $p<.10$. These differences in the distribution of looking in the different arousal conditions were reflected in a significant arousal level effect, $F(2,30)=12.47$, $p<.01$. Post hoc analyses by means of planned comparisons yielded significant F-statistics between the most and least aroused conditions, between the most aroused condition and the other two conditions combined,

Figure 6. The proportion of time spent looking at the stimulus having a faster frequency (Hz) as a function of level of arousal (all pairs combined).



1.00
.75
.50
.25
PROPORTION OF LOOKING TIME
CONDITION OF TESTING
Pre unswaddled
Pre swaddled & Post unswaddled
Post swaddled

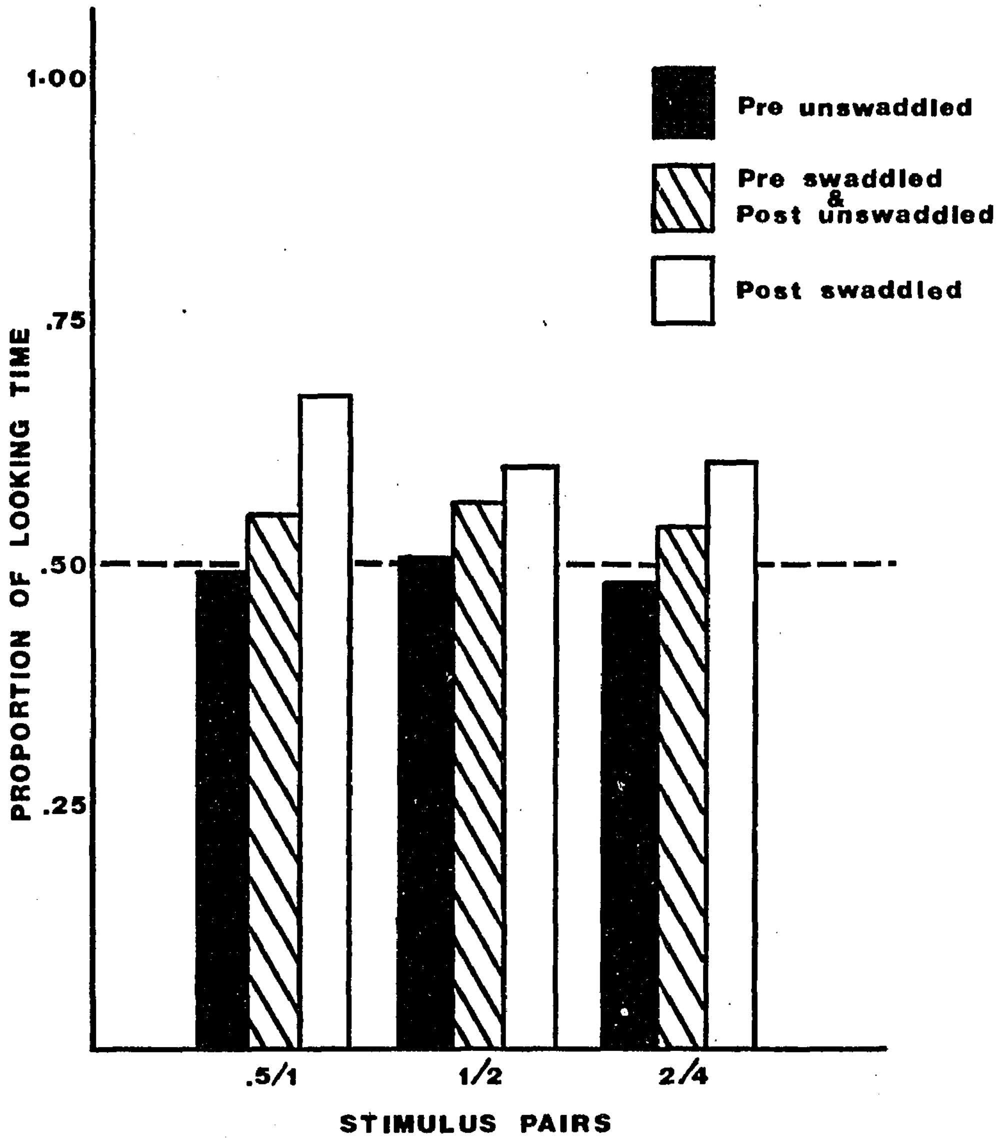
and between the least aroused condition and the other two conditions combined. As can be seen in Fig. 7, each of the three stimulus pairs showed the same regular relationship between looking and level of arousal.

As was the case with the cube stimuli, the infants failure to show preferences when most aroused was due to fewer infants showing preferences when in this condition and to the direction of their preference being less consistent than when they were less aroused. When preference is defined, as in the first study, as the proportion of looking to either member being greater than .54, only half the infants showed a preference when unswaddled prior to feeding, with five of these eight infants preferring the stimulus having a slower frequency. In contrast, when swaddled after feeding, 12 infants showed a preference, and only one of them preferred the slower frequency.

The separate effects of swaddling and feeding were analyzed by comparing all the combined unswaddled conditions with all the combined swaddled conditions (Tests 1, 2, 3 and 4 vs. Tests 5 and 6), and by comparing all the combined prefeeding conditions with all the combined postfeeding conditions (Tests 1, 2, 4 and 5 vs. Tests 3 and 6). Swaddling and feeding were each found to have a significant effect on the distribution of looking, $\underline{t}(15)=2.18$, $\underline{p} < .05$; $\underline{t}(15)=4.65$; $\underline{p} < .01$.

To determine whether the level of arousal affected the proportion of looking at the stimulus with a faster frequency by influencing the amount of looking at either or both members of the stimulus pairs, the mean looking time to the member of the stimulus pair having a faster frequency and the mean looking time to the member of the stimulus pair

Figure 7. The proportion of time spent looking at the stimulus having a faster frequency (Hz) as a function of level of arousal for each stimulus pair.



1.00
.75
.50
.25
PROPORTION OF LOOKING TIME
Pre unswaddled
Pre swaddled & Post unswaddled
Post swaddled
.5/1
1/2
2/4
STIMULUS PAIRS

having a slower frequency were analyzed separately. Significant main effects of arousal level were found for both time spent looking at the light going on and off at a faster frequency $F(2,30)=3.91$, $p < .05$, and time spent looking at the light going on and off at a slower frequency, $F(2,30)=.54$, $p < .01$. Thus, state influenced differential looking by causing both an increase in looking at the stimulus with the faster frequency when the infants were less aroused ($\bar{X}=20.8$, 23.9 and 26.5 sec for the three levels of arousal from most to least aroused), and a decrease in looking at the stimulus with a slower frequency when they were less aroused ($\bar{X}=20.9$, 19.8 and 16.3 sec for the three levels of arousal from most to least aroused). Post hoc analyses by means of planned comparisons of the effect of arousal condition on time spent looking either at the light going on and off at a faster frequency or at the light going on and off at a slower frequency did not yield any significant differences among arousal levels.

Stimulus effects

Unlike the case with the cube stimuli, analysis of variance did not indicate that the proportion of time spent looking at the stimulus having a faster frequency was affected by the particular pair of stimuli being viewed, nor was the amount of looking directed at either the stimulus with a faster frequency or the stimulus with a slower frequency affected by whether the frequencies of a particular pair of lights were faster or slower than that of the other pairs. That is, there were no significant effects of stimulus pair in any of the analyses.

Individual differences

To determine whether individual infants showed relative consistency in responding across conditions, the data were analyzed with respect to whether there was a significant main effect for subjects. There was no such subject effect for the proportion of looking. However, significant subject effects were found in the amount of time spent looking at the light with a faster frequency and in the amount of time spent looking at the light with a slower frequency, $F(15,60)=4.19$, $p < .001$; $F(15,60)=3.16$, $p < .005$; respectively. As with the cube stimuli, this indicates that the infants showed consistent individual differences in the total amount of time spent looking but not in what they were looking at.

Sex differences

No significant main effects nor interactions of the sex of the infant with arousal level were found in any of the analysis.

Sequence effects

It is possible that the obtained differences in looking behavior when the infants were fed and/or swaddled resulted not from the effects of differing levels of arousal, but from sequence effects due to the nonrandomized schedule of testing. The results do not indicate any sequence effect. On no measure was there a difference in looking behavior prior to feeding while unswaddled on the first tests on Day 1 and Day 2, or on the first and second tests on Day 1.

Attention effects

Infants did not show differences in attention when they were in different states of arousal when total amount of time spent looking was used as an index of attention. They spent the same amount of time looking in the different conditions ($\bar{X}$ per trial = 20.6, 21.4 and 20.8 sec for the most to least aroused conditions). Thus, the differences in looking behavior obtained among the different conditions were determined by factors other than the length of time an infant spent looking when more or less aroused.

Heart rate

The heart rate of the infants was recorded during the test conditions to provide an independent measure of level of arousal.

The mean heart rate was computed in each condition using the seven beats immediately prior to each stimulus onset. This value was considered the base level heart rate for each condition. Although there were six trials in each condition, the base heart rate was sometimes determined using a different number of trials because one or more pairs of stimuli were presented more than once in some test sessions and the heart rate was not scoreable on some trials. Thus, the actual number of prestimulus periods per condition varied among conditions and among infants. Infants with less than three scoreable trials for an entire condition were excluded from any analyses requiring the heart rate in that condition to complete the design. This resulted in one infant not being included in analyses comparing heart rate at different levels of arousal and four infants not being included in analyses comparing heart rate in the three prefeeding unswaddled conditions.

Base level heart rate was affected by the test condition. A comparison of the basal heart rate at the three designated levels of arousal yielded a significant difference across conditions. The mean heart rates were 176.8, 172,1 and 166.2 bpm for the highest, intermediate and lowest levels of arousal, respectively, $X_r^2(2)=16.1$, $p<.001$, Friedman analysis of variance. Twelve of the 15 infants had their highest heart rate levels during the most aroused condition and only one infant had its lowest heart rate level during this condition.

Both feeding and swaddling affected heart rate. A comparison of the basal heart rate during the combined prefeeding conditions with that during the combined postfeeding conditions yielded a significant difference, $T=16$, $N=16$, $p<.01$, Wilcoxon test, as did a comparison between the combined unswaddled and swaddled conditions, $T=19$, $N=16$, p .01, Wilcoxon test.

Heart rate was also used to measure individual consistency in responding. A comparison of the infants' base heart rate during the three prefeeding unswaddled conditions showed a high degree of concordance, $W=.88$, average $r_s = .83$, $X^2(11)=29.0$, $p<.005$, Kendall's coefficient of concordance. This concordance indicates that infants could be reliably characterized in terms of their basal heart rate when unswaddled during the prefeeding period to determine whether infants maintained this consistency not only across equivalent conditions, but also when feeding and swaddling conditions varied, a similar comparison was made across the three levels of arousal. A significant degree of concordance was found, $W=.66$, average $r_s=.49$, $X^2(14)=27.7$, $p<.02$, Kendall's coefficient of concordance. Relative to each other, infants apparently show consistent differences in their basal heart rate levels across rather widely varying conditions.

However, when male and female infants' heart rates were compared, it was found that they were differentially affected by the treatment conditions. Although the mean heart rate of the female infants was higher than that of the males when they were in the most aroused condition ($\bar{X}$ HR = 180.1 and 173.0 bpm for females and males), it was lower when they were in the least aroused condition ($\bar{X}$ HR = 164.4 and 168.4 bpm for females and males). To determine whether this differential effect was significant, a difference score was computed between the most and least aroused conditions for the heart rate of each infant. A comparison of the male and female infants' difference scores was significant, $\underline{U}=11.5$, $\underline{n}_1=7$, $\underline{n}_2=8$, $\underline{p} < .04$, Mann-Whitney test, indicating that the heart rate of the male infants was not as affected by the treatment conditions as the heart rate of the female infants.

CHAPTER IV

Study 3 - The relationship between amount of looking and stimulus magnitude.

Each test session in the first and second studies involved the presentation of three of the possible six pairs of stimuli. Although it is more typical in visual preference studies to present all possible pairs of stimuli, it is not without precedent to use selected pairs of stimuli ordered along a stimulus dimension (Jones-Molfese, 1972; Miranda, 1970). This type of procedure assumes an ordering of the stimuli along a continuum of the stimuls dimension. The stimuli were presented in this manner for two basic reasons: 1) the primary concern was not in doing a parametric study of stimulus effects, but rather with seeing whether changing an infant's level of arousal would affect the pattern of looking behavior, and 2) it was desirable to keep the number of trials per condition to a minimum in order to maximize the probability that an infant would complete all six test sessions. However, because some infants remained attentive longer than would be required for the six trials, these infants were presented with the additional pairs of stimuli needed to complete a design in which all possible pairs of stimuli are used. Although this type of design is not necessary to make judgments about preferential looking, the data obtained provided psychophysical functions against which additional hypotheses and relationships about the characteristics of the stimuli or of the infants could be tested in future studies. This procedure was used only during the postfeeding sessions so as not to interfere either with the other condtions or with the feeding schedule. For the sake of clarity, the results of these sessions are being presented separately.

Method

The two groups of infants in this study were selected subsets of the infants described previously and were tested as described for Study 1 and Study 2, respectively. The first group consisted of five infants from Study 1, two of whom were tested on both Day 1 and 2, two others only on Day 1, and one other only on Day 2. The second group consisted of 11 infants from Study 2, all of whom were tested on both Day 1 and Day 2. Table 4 shows the EGA at birth, birthweight, postconceptional age and postnatal age at the time of testing, and sex for these infants.

The infants were tested after the last session of each day. Thus, all were tested after feeding. Those tested on Day 1 were

Table 4

Characteristics of the Infants Presented

with All Possible Pairs of Stimuli

Infants from Study 1					Infants from Study 2				
EGA[a]	BW[b]	PCA[c]	PNA[d]	Sex	EGA[a]	BW[b]	PCA[c]	PNA[d]	Sex
31	990	40.0	9.0	M	31	1530	38.0	7.0	F
32	1350	37.5	5.5	M	32	1900	37.0	5.0	F
33	1680	37.0	4.0	M	32	1920	37.5	5.5	F
35	1560	39.5	4.5	F	33	1780	36.5	3.5	M
37	1630	39.5	2.5	M	33	1600	37.0	4.0	F
					34	1890	36.0	2.0	M
					34	1900	37.0	3.0	M
					35	1850	37.5	2.5	F
					36	1860	38.5	2.5	F
					37	1850	38.5	1.5	M
					37	1860	39.0	2.0	M

Note. All ages are given in weeks

[a]Estimated gestational age at birth

[b]Birthweight in grams

[c]Postconceptional age at testing

[d]Postnatal age at testing

unswaddled, and those tested on Day 2 were swaddled. At these times, an additional three pairs of stimuli were presented two times each. The additional pairs of stimuli presented to the infants from Study 1 were: 0 and 4 cubes, 0 and 16 cubes, and 1 and 16 cubes. The additional pairs of stimuli presented to the infants from Study 2 were: .5 and 2 Hz, .5 and 4 Hz, and 1 and 4 Hz.

Results

Cube stimuli

The data were analyzed with respect to the amount of time spent looking at each of the stimuli. Because of the small number of babies tested, and because there was no apparent difference between results obtained on Day 1 and Day 2, the data from these two days were combined into a single mean score for each of the stimuli for both of the infants who were tested on both days.

To examine the relationship between the amount of looking and stimulus characteristics, a measure of the amount of contour was used. The length of the sides of the plane of the cube(s) facing the infant was computed, with the realization that any contribution due to the three-dimensional nature of the stimuli was being ignored. Thus, the total amount of contour for each of the four stimuli was 0, 8, 16 and 32 in. (0, 20.3, 40.6 and 81.3 cm) for 0, 1, 4 and 16 cubes, respectively.

As seen in Fig. 8, the mean amount of looking increased with increasing contour length. Despite the small number of infants tested, the linear trend approached significance, $F(1,4)=6.08$, $p < .07$, whereas the cubic and quadratic trends did not.

To determine the function which best described the relationship between the amount of looking and contour length thus defined, a regression analysis was done with the data plotted on log-log co-ordinates. The regression equation obtained from this analysis was Mean log looking time = .75 + .30 (log contour length), with .75 and .30 being the intercept and slope of the regression line, respectively. The parameters of the power function are obtained from the slope and intercept with the slope being the power to which the contour length must be raised and the antilog of the intercept being the constant in the equation. Thus, the power function describing the best fitting curve plotted on linear coordinates is $R=5.67\ (S^{.30})$ where R is the mean amount of looking, 5.67 is the constant given by the antilog of the intercept, S is the contour length, and .30 is the power to which the value of the contour length must be raised (see Fig. 9). The correlation between amount of looking and contour length$^{.30}$ was significant, $r(18)=.63$, $p < .01$.

Frequency stimuli

The data were analyzed with respect to the amount of time spent looking at each of the stimuli. As seen in Fig. 10, the mean amount of looking increased with increasing frequencies on each day of testing. This linear trend was significant, $F(1,10)=20.94$, $p < .001$, Day 1 and Day 2 combined. A significant swaddling effect was also found,

Figure 8. Mean amount of time spent looking at each stimulus as a function of contour length in inches of cube stimuli.

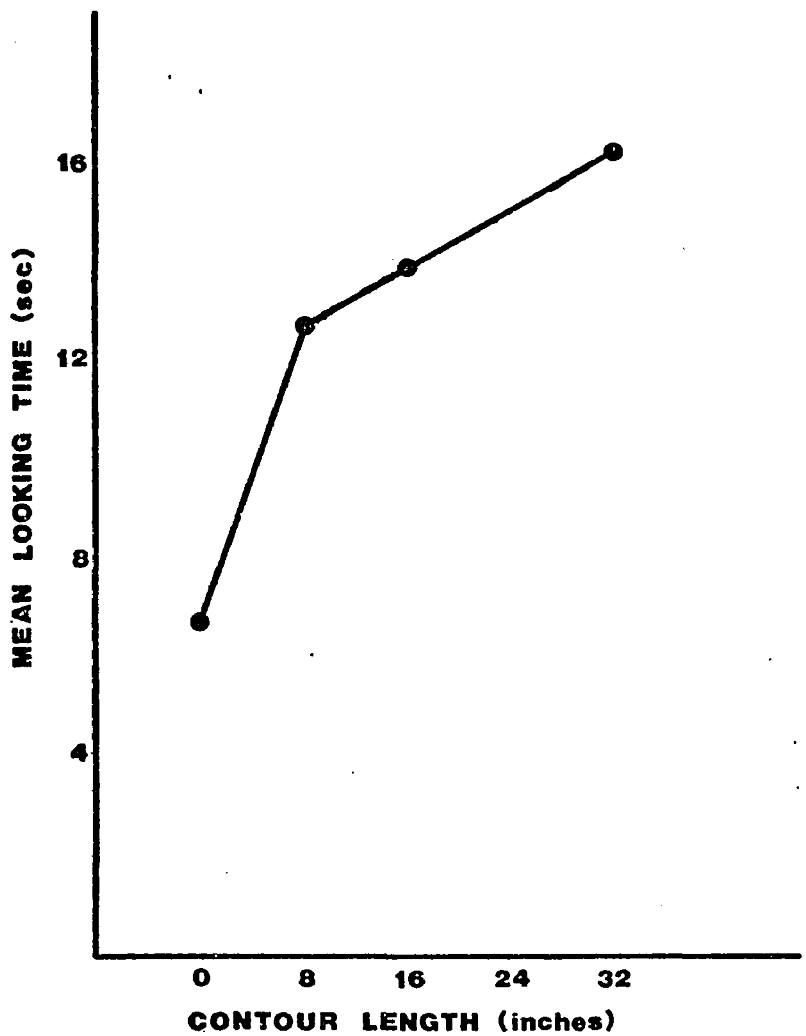

MEAN LOOKING TIME (sec)
16
12
8
4
0
8
16
24
32
CONTOUR LENGTH (inches)

Figure 9. Best fitting curve for data in Figure 8 replotted as a power function, $\underline{R} = 5.67(\underline{S}^{.3})$; that is, mean looking time as a function of (contour length in inches)$^{.3}$. Data points are for observed means.

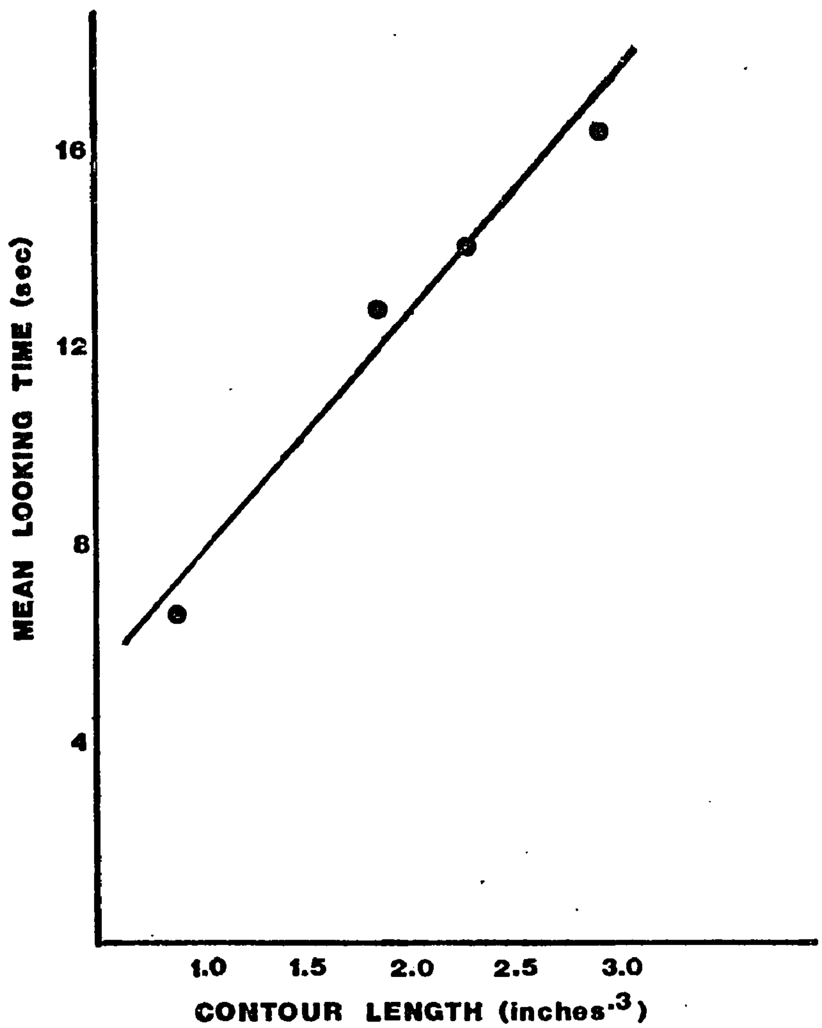
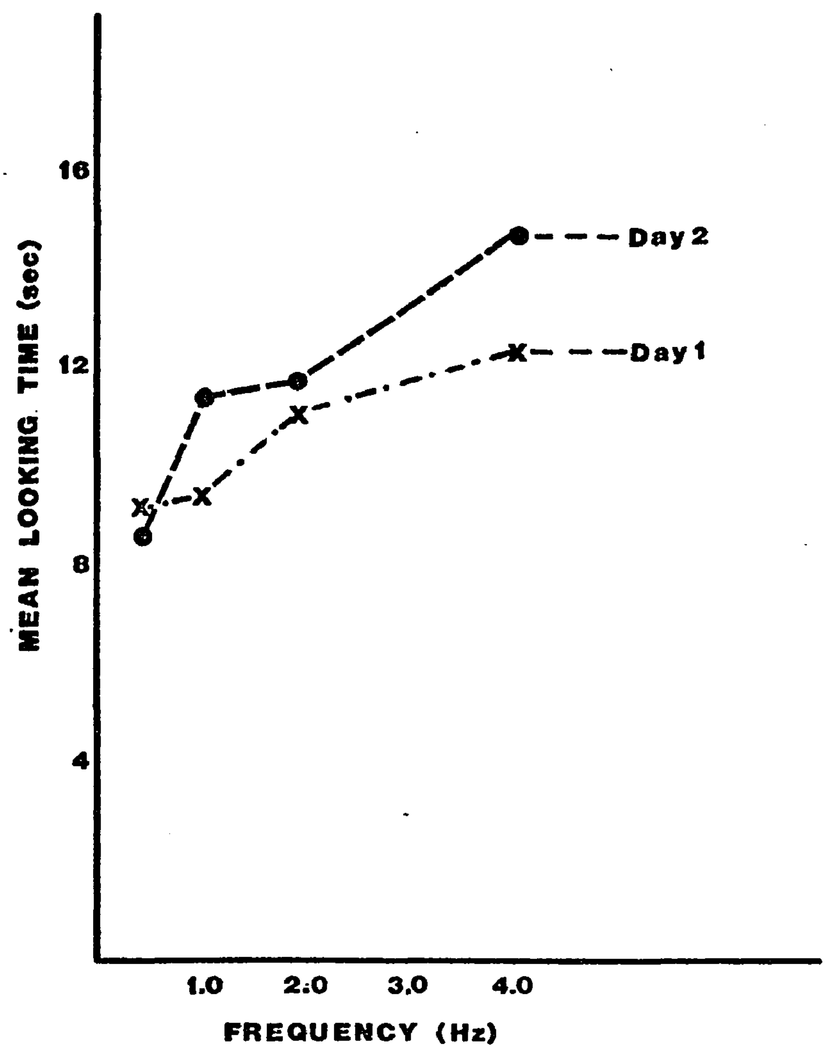

16
12
8
4
MEAN LOOKING TIME (sec)
1.0
1.5
2.0
2.5
3.0
CONTOUR LENGTH (inches·3)

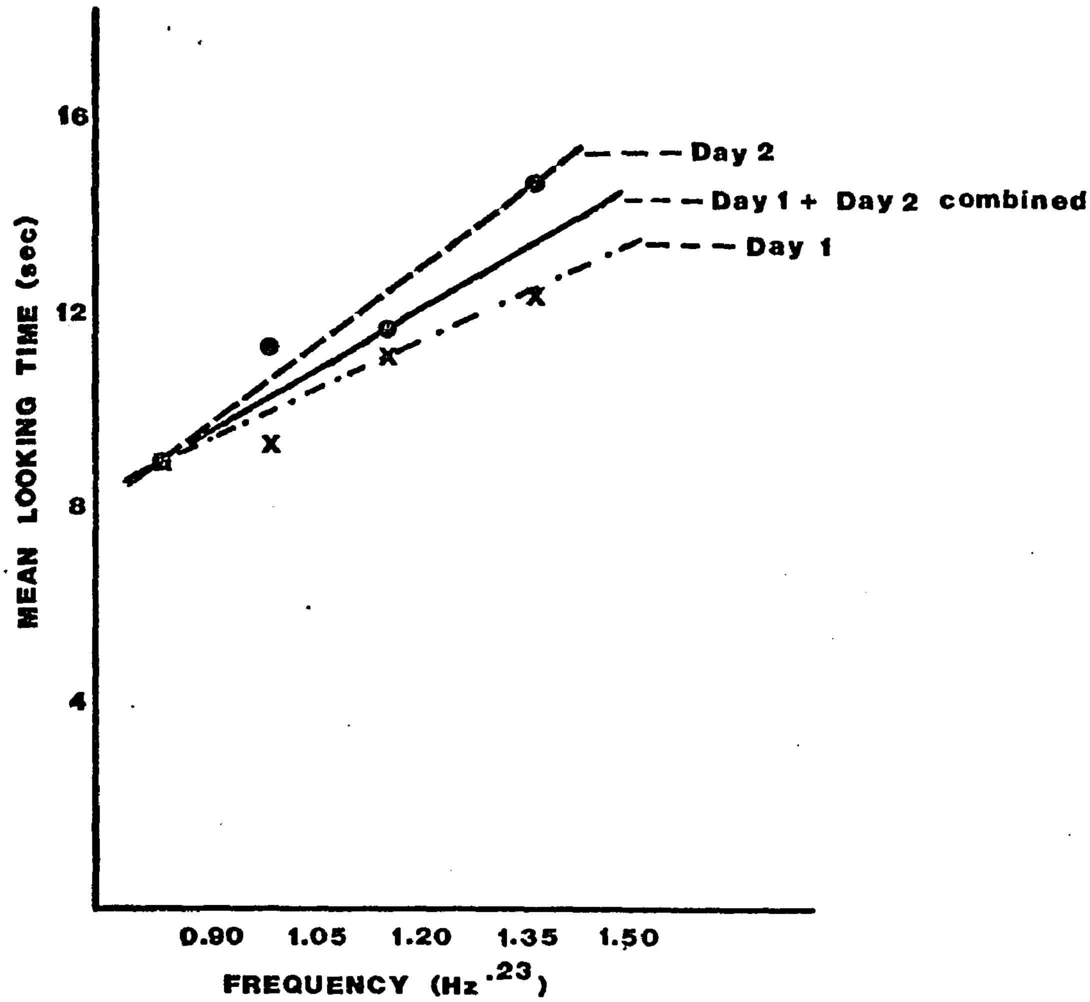
Figure 10. Mean amount of time spent looking at each stimulus as a function of frequency in Hz for Day 1 and Day 2.


MEAN LOOKING TIME (sec)
16
12
8
4
Day 2
Day 1
1.0
2.0
3.0
4.0
FREQUENCY (Hz)

$\underline{F}(1,10)=9.07$, $\underline{p} < .01$, Day 1 vs. Day 2 testing.

To determine the function which described the best fitting curve, a regression analysis was done with the amount of looking as a function of the frequency with which the lights went on and off plotted on log-log coordinates. This was done for each day separately and the two days combined. No difference was found between the regression lines obtained for Day 1 and Day 2, although the difference in the slopes of the lines (i.e., .21 for Day 1 and .25 for Day 2) was in the predicted direction. The power functions which describe the best fitting curves on linear coordinates are: $\underline{R} = 9.12(\underline{S}^{.21})$, $\underline{R} = 10(\underline{S}^{.25})$, and $\underline{R} = 9.55(\underline{S}^{.23})$ for Day 1, Day 2, and the two days combined, respectively (see Fig. 11). The correlations between amount of looking and frequency $^{.23}$ were significant for Day 1, Day 2, and Days 1 and 2 combined, $\underline{r}(42)=.36$, $\underline{p} < .05$; $\underline{r}(42)=.48$, $\underline{p} < .01$; $\underline{r}(42)=.42$, $\underline{p} < .01$; respectively.

Figure 11. Best fitting curves for data in Figure 10 replotted as power functions (see text for functions); that is, mean looking time as a function of $(\text{frequency})^{.23}$. Data points are for observed means (**X** = Day 1, ● = Day 2).



MEAN LOOKING TIME (sec)
16
12
8
4
0.90
1.05
1.20
1.35
1.50
FREQUENCY (Hz $^{.23}$)
Day 2
Day 1 + Day 2 combined
Day 1

CHAPTER V

DISCUSSION

The results of the present investigation indicate that the distribution of attention in premature infants is, in part, determined by their internal condition or state. Changes in the infants' feeding and swaddling condition resulted in changes in the visual stimuli to which they preferentially attended. Infants spent a different proportion of time looking at the members of pairs of stimuli when they were at three designated levels of arousal (low, medium and high). The proportion of time spent looking at the more intense stimulus increased from the condition in which the infants were most aroused (unswaddled prior to feeding) to that in which they were least aroused (swaddled postfeeding).

The a priori designation of the different conditions in terms of their presumed effect on arousal level received support from the finding that the infants' base heart rate level in the different conditions exhibited the expected progression. The infants had the lowest heart rates when swaddled postfeeding and the highest rates when unswaddled prefeeding. As there is an association between heart rate and level of arousal, it can be assumed that the conditions of testing influenced the level of arousal of the infants in the anticipated manner.

That the effects of arousal on differential looking are not simply a consequence of disruption of behavior at higher levels of arousal is suggested by the findings that there were no differences in overall level of attention at the different arousal levels. Regardless of their feeding and swaddling condition, infants spent equivalent amounts of time looking. Assuming that the amount of time spent looking can be used as an index of attention, any difference in the distribution of looking at for members of the stimulus pairs was due to differences in the stimuli to which infants attended, and was not an artifact of the infants looking for longer or shorter periods of time when more or less aroused.

Level of arousal influenced the distribution of looking in a similar manner regardless of whether the stimuli varied in size and number of elements or varied in frequency of illumination. Thus, although the mean amount of time spent looking did not differ across conditions, the proportion of looking at the stimulus having more elements or a faster frequency was inversely related to arousal. Infants showed consistent increases in differential looking as arousal was reduced, with each pair of stimuli showing the same regular relationship. Infants shifted from showing no preference between the members of a pair when most aroused to preferring the stimulus having more elements or a faster frequency when least aroused.

The obtained inverse relationship between level of arousal and intensity of stimulation was predicted by those theoretical positions which contend that young infants respond on the basis of effective intensity of stimulation. This relationship would not have been predicted by views which limit their definition of changes in intensity to changes in physical stimulus (e.g. luminance), and by theories which propose that young infants respond to the qualitative features of visual stimuli (e.g. pattern configuration).

Optimal level theory states that there is a level of stimulation to which an infant will preferentially respond (Dember and Earl, 1957). When presented with stimuli which differ along a common dimension, infants should attend most to that stimulus which produces an optimal level of stimulation and decreasingly to stimuli that diverge further and further from this level. Although the findings of the present study can be interpreted within the framework of optimal level theory, the theory would have to be explicitly extended to include all factors which may influence the level of stimulation in order to account for the present findings. If this is done, then it can be stated that the stimulus which produces the optimal level of stimulation will vary not only as a function of stimulus characteristics, but also as a function of changes in short or long term characteristics of the organism. For example, if the infant's level of arousal is reduced, a higher intensity stimulus will be necessary for the optimal level of stimulation to be achieved.

Viewed in this manner, the optimal level is essentially controlled by a kind of homeostatic mechanism analagous to mechanisms possessing negative feedback. That is, it would operate to increase the amount of stimulation when the amount present internally was reduced (at low levels of arousal), and to decrease or even block incoming stimulation when internal stimulation was heightened. An inverted

U-shaped response curve would be predicted in which looking behavior would be related to the effective intensity of stimulation. Looking behavior would increase as the effective intensity increased, with maximum looking occurring at the optimal level or peak of the curve. Looking behavior would decrease as the effective intensity increased beyond this level. However, shifted optimal level curves would be obtained for the same objective stimuli with shifts in arousal because of differences in the effective intensity.

Extending optimal level theory in this way brings it very close to Schneirla's Approach/Withdrawal intensity hypothesis (1965) by having it incorporate Schneirla's concept of effective intensity. The major difference between the two theories is that the A/W intensity hypothesis postulates a biphasic response curve, each part of which is controlled by opposing systems, namely, approach processes and withdrawal processes. Approach processes have lower thresholds than withdrawal processes and generally tend, when activated, to orient or bring the organism closer to the source of stimulation. Withdrawal processes, with higher thresholds, tend to orient or take the organism away from the source of stimulation. The activation of either system depends on the effective intensity of stimulation. When the intensity of stimulation is low (but suprathreshold), approach responses will be seen. As the intensity increases, approach responses increase up to some maximum level. If the intensity increases beyond this level, approach responses decrease. Additional increases in intensity will cause withdrawal responses to be seen when the threshold for withdrawal processes is reached. At the point of intersection between the approach and withdrawal response curves, neither response occurs. Increasingly higher intensities of stimulation produce increasing withdrawal responses. The manner in which arousal might influence the effective intensity could be that thresholds would become lower as arousal increased. Thus, in the most aroused conditions, infants would have the lowest thresholds and in the less aroused conditions, their thresholds would be higher. Thresholds would be highest when infants were even less aroused, as when asleep. The effective intensity of a stimulus then would be such that at the highest level of arousal the same stimulus which was attended at lower levels of arousal would have an effective intensity sufficient to reach withdrawal thresholds.

With regard to the present study, when infants were most aroused (and presumably had high levels of internal stimulation), the same visual stimulus which was attended to at lower levels now had an effective intensity which was either beyond the withdrawal threshold or at the intersection of the approach and withdrawal curves. The fact that no preferences were shown by the infants when they were in the most aroused condition suggests that the effective intensity reached the point of intersection when infants were at the highest levels of arousal. When infants were least aroused their preferences for the higher intensity stimulus indicates that the effective intensity was near or at the peak of the approach curve.

Support for this interpretation comes from looking at the pattern of responding to the individual pairs of stimuli. Although differential looking decreased with increasing arousal in all stimulus pairs, the pattern of looking at the pair containing the most intense stimuli was somewhat different from the pattern of looking at the two lower intensity pairs. Thus, with the cube stimuli, in all arousal conditions, infants tended to look more at the higher intensity member of a pair when tested with the intermediate and least intense pairs of stimuli (1/4 cubes and 0/1 cubes). However, when tested with the most intense pair (4/16 cubes), they tended to look more at the lower intensity stimulus when they were at the highest or intermediate levels of arousal, and only looked more at the higher intensity stimulus when they were in the least aroused condition. This suggests that the effective intensity of the stimulus having 16 cubes was above the withdrawal threshold for infants when they were moderately or highly aroused, so that they were starting to look away from this stimulus. A similar interpretation is suggested by the data from the infants tested with the frequency stimuli. In all arousal states the infants also tended to look more at the higher intensity member of a pair when looking at the pairs containing the intermediate and slowest frequencies (1/2 Hz, and .5/1 Hz). However, when they were tested with the pair with the fastest frequencies (2/4 Hz), they tended to look at the slower stimulus when most aroused and at the faster stimulus when they were at moderate and low levels of arousal.

Thus, the effective intensity of the 4 Hz stimulus (as with the 16 cube stimulus) may have been higher than the withdrawal threshold for infants when they were most aroused, and they may have started to show looking away responses.

Although the A/W intensity hypothesis requires that the infants shift from preferring the less intense stimulus when most aroused to preferring the more intense stimulus when least aroused, the current findings give partial support by the fact that the infants did shift from no preference to preferring the more intense stimulus between the most and least aroused conditions. It therefore appears that the A/W intensity hypothesis provides a better interpretation for the findings of this study than does optimal level theory. That is, optimal level theory, as typically conceived, only accounts for responding in relation to objective stimulus effects and only accounts for responding oriented toward the stimulus. Extending optimal level theory to include the concept of effective intensity serves to make it more similar to A/W intensity hypothesis. Although significant withdrawal responses were not found in the present study, the direction of responding with the highest intensity stimuli indicates that an interpretation including this type of responding might be necessary if a wider range of stimulus intensities were used.

A physiological interpreation of the present findings may add to the understanding of the mechanisms mediating the effect of arousal on differential looking. Infants of the age examined are responsive to visual stimulation as shown in studies of both behavior (Jones - Molfese, 1972; Miranda, 1976; Werner and Siqueland, 1978) and visually evoked potentials (Engel and Benson, 1968; Hrbek, Karlberg and Olsson, 1973; Hrbek and Mares, 1964; Umezaki and Morrell, 1970; Watanabe, Iwase and Hara, 1972; Vaughan, Note 3). Neural responding, regardless of the level of the visual system examined is such that due to excitatory and inhibitory influences produced when stimulation impinges onto receptive fields, there is a "fine tuning" of the system. Thus, within the range of stimulation to which they are sensitive, neurons show maximal firing rates to specific levels of spatial and temporal frequencies impinging on the visual system from the visual field. Increasing external stimulation up to some level causes increasing changes in firing rate. Beyond this level, increasing stimulation causes decreases in firing rate.

These types of changes in the neural firing rate reflect the degree of activation of the system and may be correlated with infant visual attention. They may also represent systematic information for response systems connected to such visual system influences. Karmel and his co-workers (Karmel et al., 1977; Karmel and Maisel, 1975) argue that such changes are related to the spatial and temporal stimulus frequencies that impinge on the spontaneously acting visual system. They assume a constancy in the basic spontaneous level and a constancy of the dynamic range of change (degree of activation possible) in the normal alert and attentive older baby. They also assume that the greatest attentional effects of the stimulus are coincident with maximal activation effects on the central nervous system. They argue that the spatial and temporal event that will produce such effects will be controlled by internal characteristics that limit the degree to which such changes can be reflected in the gross brain electrical activity level inherent to the EEG and the evoked potentials recorded as a result of stimulation.

A correspondence has been found between such hypothetical levels of neuronal activity and attention in that the stimulus which produces the maximum peak-to-peak amplitude of the evoked response (Karmel, Hoffmann and Fegy, 1974) and the greatest continuous signal strength in the photically driven EEG (Karmel et al., 1977) also produces the maximum amount of looking at that stimulus. Thus, the neuronal activity hypothesis (Karmel and Maisel, 1975) predicts that a matching occurs such that the higher the level of neuronal changes in activity produced by a particular stimulus, the higher is the level of attention.

In the present study, preferential responses were influenced not only by the stimulus, but also by the infants' state. If the neuronal activity hypothesis is to account for such influences, it must be extended to explain the effect of such arousal on looking behavior. One way might be to modify the implicit assumption of constancy in the spontaneous level of activity from which the range of neuronal changes are determined. This modification would allow for an extension of the hypothesis such that the dynamic range of changes would be determined not only by the stimulus that maximized the changes, but also by any influences that affected the spontaneous background level of the system. Thus, to better understand attention, in light of the results reported here, the neuronal activity hypothesis would have to incorporate the possibility that a dynamic range of potential change exists, but that it is influenced among other things by the level of arousal of the organism at any point in time.

Questions arise as to the level in the visual system at which changes have the most influence in governing the attentional responses of very young infants, and of developmental changes which may take place in the determination of such attentional responses.

Woodruff (1978) reviewed the evidence for sub-cortical control of visual behavior in very young infants and found concordance among anatomical, EEG and behavioral developmental patterns. Prior to three months of age the neurons in the occipital cortex are undersoging a great deal of differentiation especially with respect to dendritic branching and arborization (Purpura, 1975), and the visual pathways are not fully myelinated (Minkowski, 1967). The EEG and visual evoked potentials undergo corresponding changes (Ellingson, 1967a, 1967b; Vaughan, Note 3). Lindsley and Wicke (1974) found a concordance between EEG and behavioral changes at analogous ages in infant rhesus monkeys and humans. They contended that the period when the infant progresses from a subcortical to cortical level of functioning is reflected in a significant change in cortical organization with the onset of organized rhythmic occipital activity at about three months of age in humans. Thus, the age changes in the "alpha" frequency coincides with changes in early reflex patterns such that the reflexes disappear, presumably due to increased cortical inhibition of lower brain areas. Gerrity and Woodruff (Note 4) reported similar findings and stated that the onset of "alpha" rhythm marked the time when individual infants go from visual responses such as fixation and following which could be mediated subcortically to responses requiring cortical integration such as preferences for form and for novelty, and habituation to visual stimuli.

A number of other investigators have found that it is likely that subcortical mechanisms, such as those originating in the superior colliculus and pulvinar, control responses in very young infants (Bronson, 1974; Hoffmann, 1973, 1978; Karmel and Maisel, 1975; Salapetek, 1975). Bronson (1974) postulated two different visual systems: a geniculo-striate primary visual system capable of analyzing patterns, and a subcortical secondary visual system not capable of such analyses, which is the prepotent system during the first month or two of life. Bronson provided both physiological and behavioral data, he parsimoniously maintained that mediation should be attributed to the primary system only when it could not be shown that the secondary system was capable of mediating the behavior.

Even in older infants and adults whose responding to patterned input is generally considered to be mediated cortically, the possibility of responding to other stimulus factors subcortically would not be precluded. Thus, ablation of the visual cortex in monkeys appears to eliminate pattern discrimination, but does not substantially affect responding to total luminous flux (Kluver, 1941, 1942) or to movement of contours (Weiskrantz, 1963). Further, cats after ablation of the neocortex, including the visual cortex, show appropriate responding to the shallow side of the visual cliff (Meyer, 1963). Changes in size or brightness do not affect responding to patterns in older infants whose responses are governed by cortical systems, whereas these types of changes do affect responding in very young infants whose responses are likely to be governed by subcortical mechanisms (Maisel and Karmel, 1978; McCarvill and Karmel, 1976; Ruff and Turkewitz, 1975, 1979).

Thefore, it seems reasonable that visual input could be integrated subcortically in terms of its intensity, and that the level of activation produced by this integrative effect could govern attention in young infants. The effects of arousal on this subcortical system would then be to alter the amount of activation by producing higher or lower levels of spontaneous background activity which the external stimulation must in some way organize to produce attention.

As reviewed earlier, the importance of state of arousal as a variable with regard to responding to stimulation has been shown by many researchers. Its importance as a factor influencing responding is accepted as a "given" in certain types of research, especially in the field of infancy. For instance, studies in which movement has been restricted by swaddling have found reduced arousal as measured by heart rate, amount of crying or amount of sleep (Brackbill, 1971; Giacoman, 1971; Lipton et al., 1965). However, measures of responsiveness in these studies have utilized the amount of responding rather than differential responsiveness. Studies which varied feeding condition have also shown the importance of this variable on responsivity (Giacoman, 1971; Malcuit-Pomerleau and Clifton, 1973; Turkewitz, Fleischer et al., 1966) and on differential responding (Malcuit-Pomerleau and Clifton, 1973; Turkewitz, Birch et al. 1966).

Reduction in arousal due to swaddling has been attributed to both the soothing effects of continuous tactile stimulation (Brackbill, 1971) and the reduced level of proprioceptive-tactile stimulation accompanying muscular restraint (Giacoman, 1971; Lipton et al., 1965). Studies which have found effects of swaddling on arousal have equated for the effects of both tactile stimulation and temperature by having unswaddled infants clothed in equivalently weighted clothing. It is therefore difficult to see how swaddling would produce more continuous tactile stimulation or higher ambient temperature than that experienced by the unswaddled but clothed control infants. It is more likely that swaddling reduces reticular stimulation from proprioceptive afferents by reducing motor activity. Consequently, in young infants with immature cortical inhibitory systems, swaddling would act to break the positive feedback loop between increased motor activity through collaterals causing increased proprioceptive stimulation of the reticular formation and higher levels of motor activity facilitated by this increased reticular stimulation.

Reduction in arousal due to feeding has been attributed to both the infant being at the end of a wake cycle after having been kept awake during feeding (Clifton, 1978) and the reduction in stimulation by reducing stomach contractions (Turkewitz, Birch, et al., 1966; Turkewitz, Fleischer, et al., 1966). Lowered arousal after feeding is not likely to be due to the amount of time spent awake or types of stimulation encountered during the awake period. In the present study, postfeeding testing did not always occur after infants had been awake for the same amount of time. Thus, if they were not able to be kept awake during testing, infants were allowed to sleep for varying periods of time after feeding before being awakened. In addition, the methods used to either waken an infant who had fallen asleep or maintain wakefulness in an infant who was on the verge of doing so, involved considerable stimulation. Nursery procedures also provided different amounts of stimulation to the infants prior to testing. Therefore, the infants had been awake for varying periods of time before being tested, and had received varying amounts and kinds of stimulation. The fact that feeding was effective in reducing arousal in infants having so much variability of stimulation therefore suggests an effect due to feeding per se. The finding that feeding and swaddling together produced a greater effect on arousal than did either alone, suggests that they were both acting on a common system. This system probably involves the reticular formation and possibly areas of the hypothalamus and thalamus which are also involved in the mediation of tonic levels of arousal.

Although it is likely that the reticular formation is involved in the mediation of arousal, there are varying opinions as to the mechanisms by which it acts, the degree to which its action is really due to mediation by hypothalamic and thalamic systems, and the manner in which swaddling and feeding act to reduce arousal. The reticular formation receives collaterals from all sensory afferents, has projections to most areas of the brain including the thalamus, cortex and limbic system, has projections to peripheral sensory systems, and receives input from most other areas of the brain as well. Stimulation of the reticular formation, either directly or through stimulation of any of the sensory modalities, has been shown to reduce the amplitude of evoked potentials to stimulation of another modality (Hernandez-Peon, Scherrer and Jouvet, 1956; Hernandez-Peon, Scherrer and Velasco, 1956; Horn, 1960). This reduced evoked potential may be a consequence of direct stimulation of the reticular formation or of indirect feedback from cortical stimulation on the reticular formation. In addition, the reduction evoked does not necessarily mean reduced responding. It has also been shown that the signal-to-noise ratio may be even greater with reticular stimulation because of decreased spontaneous levels of random firing in background activity of the reticular formation due to the increased activation of inhibitory neurons from the cortex (Bonvallet, Dell and Heibel, 1954).

Studies have, in fact, shown increased responding and better performance on tasks involving discriminations and reaction time with increased arousal. For example, in adults, attention to a flash of light or a click enhanced the evoked response of the attended modality compared to the ignored modality (Spong, Haider and Lindsley, 1965), and in monkeys trained on a discrimination task, reticular stimulation increased the percent of correct responses and decreased the latency of responding (Fuster, 1958). However, it would probably be generally accepted that there is an inverted U-shaped relationship between arousal level and performance such that either too much or too little arousal would adversely affect performance (Berlyne, 1971; Hebb, 1949). It thus appears that the reticular formation functions to provide a tonic level of arousal against which phasic input can be analyzed.

Young infants, however, appear to have little, if any, cortical inhibitory influences on lower brain areas. This is seen behaviorally with studies of reflexes showing the disappearance of the reflexes coincidental with maturation of cortical inhibitory systems at about two months of age (McGraw, 1945; Gerrity and Woodruff, Note 4) as evidenced by anatomical studies of dendritic arborization (Purpura, 1975) and myelination (Minkowski, 1967). Therefore, nonspecific reticular stimulation from internal sensory afferents would serve to increase spontaneous firing rates without a concommitant increase in inhibitory control. It has indeed been shown that premature and high-risk infants tend to be more excitable and irritable and less easily soothed than normal full-term infants (Howard, Parmalee, Kopp and Littman, 1976; Kurtzberg et. al., 1979; Prechtl, 1963).

Thus, in the present study, when infants were in the most aroused condition, stimulation of the reticular formation, from both movement and stomach contractions, without concomitant inhibitory influences, could have produced high tonic levels of spontaneous background activity which were self-perpetuating. Only by reducing the amount of afferent stimulation by feeding and swaddling, could the tonic levels of activity be decreased sufficiently to allow for processing of the phasic stimulus input above the noise.

For some infants, however, reduction of afferent stimulation alone might not be effective in bringing this about. Before feeding and swaddling could act to decrease the high levels of background activity, some degree of maturation of the nervous system might be necessary. This possibility is suggested by the finding that the relationship between level of arousal and the distribution of looking at stimuli with differing numbers of elements differed in male and female infants. Females showed a larger increase in looking at the more intense stimulus than males did when they were in the least aroused condition. The increased susceptibility of female infants to the effects of feeding and swaddling may be interpreted as due to a difference in maturity level of the central nervous system. As compared to male infants, female infants are precocial with respect to a number of aspects of development and are generally in better condition and less prone to stress (Bentzen, 1963; Berg, Adkinson and Strock, 1973; Garai and Scheinfeld, 1968; Singer, Westphal and Niswander, 1968). The responses of female premature infants to tactile stimulation have been shown to be more similar to the responses of full-term infants than those of male premature infants (Rose, Schmidt and Bridger, 1976), and this similarity has been shown to be even greater in older born than younger born female premature infants (Lewkowicz, Gardner and Turkewitz, in press). Their increased looking at the stimulus having more elements when least aroused appears to reflect this higher degree of maturity, as an age-related shift in preferences toward stimuli with more elements has been shown (Brennan et al., 1966; Fantz and Fagan, 1975). In addition, in comparison to female infants, male infants have higher levels of motor activity and irritability which are taken as indices of a greater degree of disorganization (Beckwith and Cohen, 1978; Moss, 1967; Prechtl, 1963) and are reflected in the poorer performances of male premature infants on mental and motor development tests at one year of age (Braine, Heimer, Wortis and Freedman, 1966).

In the present study, although differences were found between male and female infants when they were least aroused, no differences were found when they were most aroused. It is therefore possible that the obtained difference in the effects of feeding and swaddling on differential looking is due to differences in soothability of boys and girls. Such an interpretation is supported by the finding that males showed less of a reduction in heart rate with feeding and swaddling than did females. This suggests that boys could not as readily be calmed as girls, a finding which is also consistent with the view that the girls were better functioning as adaptability and soothability have been related to the functional integrity of the central nervous system (Howard, et. al., 1976; Korner, 1971; Parmalee, 1975; Thomas, Birch, Chess, Hertzig and Korn, 1963).

Paired comparisons using all possible pairs of stimuli

The results obtained in the study involving the presentation of all the possible pairs of stimuli had not been anticipated. The two previous studies with similar aged infants (Jones-Molfese, 1972;

Miranda, 1970) had 1) only presented ordered pairs of stimuli as was done in looking at the effects of arousal level on visual preferences in the present study, 2) only presented either two-or three-dimensional checkerboard-like stimuli and not stimuli having different temporal frequencies, and 3) indicated that preferences seemed to be for one or four cubes, certainly not for sixteen cubes.

In the present study, however, linear trends were found for both types of stimuli, and the most preferred stimulus was the one with the highest intensity for both the stimuli varying in size and number of elements and the stimuli varying in frequency of lights going on and off. This preference for a stimulus having 16 cubes and a stimulus having a frequency of 4 Hz is concordant with studies showing a predominant EEG frequency in awake infants of this age of 4-7 Hz (Ellingson, 1967b; Hagne, Persson, Magnusson and Petersen, 1973) and driving of visually evoked potentials by a mean optimal frequency of 3.6 or 4.0 Hz flashes of light (Ellingson, 1967a).

These findings, however, suggest that in future studies the range of stimuli should be extended. Because they were obtained only from infants who had been fed and therefore had reduced levels of arousal, and because with reductions in level of arousal infants showed increasing preferences for the higher intensity stimulus of a pair, it is likely that the looking behavior of infants in the most aroused condition would show an inverted U function as would be predicted by the previous studies.

It is a matter of speculation as to just where the peak of this curve would be. However, support for this hypothesis is provided by the finding of a swaddling effect in the present study. Although no difference was found between the slopes of the regression lines for the unswaddled and swaddled conditions, there was a tendency in the correct direction. Thus, the curve for the unswaddled condition might have shown a peak at a lower stimulus intensity than the curve for the swaddled condition, if a wider range of stimulus intensities had been presented.

The major importance of the obtained linear trends is that they specify quantitative functions of responding to varying levels along a dimension of stimulation which can be expressed parsimoniously in terms of psychophysically meaningful equations. Such equations could be used in subsequent studies as regression lines against which factors, such as the degree of risk, can be evaluated quantitatively.

Appendix

Table A

____
Patient Identification

DETERMINANTS OF ATTENTION IN PREMATURE INFANTS

INFORMED CONSENT

I, ________________________, bearing the relationship of __________ to infant ________________, hereby give consent for the participation of my child in the study of visual preferences in premature babies on the 8-South Neonatal Unit of Jacobi Hospital. I have read the description of the study given below and understand that my child may receive the procedures listed below.

Background:

The way in which a baby reacts to his surroundings is important for his learning about the world. Even newborn babies look at objects around them. When they are shown two different pictures or objects at the same time, they usually look at one of them more than at the other. Why they prefer to look at one object rather than another can be determined by many things. We believe that one of the things that determines what a baby prefers to look at is how excited or calm he is while he is looking. For example, it is possible that when the baby is excited he prefers to look at simple pictures or objects, and when he is calm he prefers to look at more complicated things.

Different babies prefer to look at different things. We believe that this may be because of differences in how excited or calm they normally are. If this is so, it might be possible to change what they pay attention to by shifting their level of excitability. This may be helpful for some premature babies because they tend to prefer looking at less complicated things than full-term babies, and this may slow their development.

Procedure:

1. Your baby has been selected from babies in the premature nursery of Jacobi Hospital because he/she is in a stable condition.

2. The baby will be sitting in a semi-reclining position supported by an infant seat which is placed inside the isolette or bassinette.

3. We will show him/her a series of black and white cubes. We will observe how long he/she looks at each. We will record his/her heart rate by placing small recording devices on his/her chest.

4. We will examine your baby's preferences when he/she is quiet, as well as when he/she is more and less excited. By testing the baby before and after feeding and while he/she is wrapped up and unwrapped, we hope to be able to see what effect his/her condition has on what he/she pays attention to. To get a clearer idea of the baby's

preferences, we will examine him/her on two different days. Each test will last less than one hour and will not interfere with the baby's feeding or care.

Most babies seem to find this kind of testing interesting and will spend fairly long periods of time looking at objects of the type we will be showing them.

I have received information explaining this study and the procedures that are involved. I understand that I am free to withdraw my consent and discontinue my infant's participation in this project at any time without in any way affecting the care he/she will receive.

Signature

Address

Witness

Date

Table B

____
Patient Identification

DETERMINANTS OF ATTENTION IN PREMATURE INFANTS

INFORMED CONSENT

I, ________________________, bearing the relationship of ____________ to infant ________________, hereby give consent for the participation of my child in the study of visual preferences in premature babies on the 8-South Neonatal Unit of Jacobi Hospital. I have read the description of the study given below and understand that my child may receive the procedures listed below.

Background:

The way in which a baby reacts to his surroundings is important for his learning about the world. Even newborn babies look at objects around them. When they are shown two different pictures or objects at the same time, they usually look at one of them more than at the other. Why they prefer to look at one object rather than another can be determined by many things. We believe that one of the things that determines what a baby prefers to look at is how excited or calm he is while he is looking. For example, it is possible that when the baby is excited he prefers to look at simple pictures or lights that go on and off slowly, and when he is calm he prefers to look at more complicated or faster changing things.

Different babies prefer to look at different things. We believe that this may be because of differences in how excited or calm they normally are. If this is so, it might be possible to change what they pay attention to by shifting their levels of excitability. This may be helpful for some premature babies because they tend to prefer looking at less complicated things than full-term babies, and this may slow their development.

Procedure:

1. Your baby has been selected from babies in the premature nursery of Jacobi Hospital because he/she is in a stable condition.

2. The baby will be sitting in a semi-reclining position supported by an infant seat or on the experimentor's lap.

3. We will show him/her a series of lights that go on and off at different rates. We will observe how long he/she looks at each. We will record his/her heart rate by placing small recording devices on his/her chest.

4. We will examine your baby's preferences when he/she is quiet, as well as when he/she is more and less excited. By testing the baby before and after feeding and while he/she is wrapped up and unwrapped, we hope to be able to see what effect his/her condition has on what he/she pays attention to. To get a clearer idea of the baby's preferences, we will examine him/her on two different days. Each test will last less than one hour and will not interfere with the baby's feeding or care.

Most babies will spend fairly long periods of time looking at the types of things we will be showing them.

I have received information explaining this study and the procedures that are involved. I understand that I am free to withdraw my consent and discontinue my infant's participation in this project at any time without in any way affecting the care he/she will receive.

______________________ Date	______________________ Signature
______________________ Witness	______________________ Address

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