A SEARCH FOR THE OBLIQUE EFFECT IN YOUNG INFANTS

By

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ABSTRACT

For a wide variety of visual tasks, subjects perform more poorly when stimuli are oriented obliquely than when they are oriented vertically or horizontally. It is generally believed that this 'oblique effect' has two manifestations. One is meridional anisotrophy, i.e., lower acuity for obliquely oriented stimuli than for vertical or horizontal stimuli. The second is poor oblique discrimination; i.e., greater difficulty discriminating between mirror-image oblique stimuli than between vertical and horizontal ones, even when the stimuli are above the threshold of acuity. This thesis explores whether these two phenomena are in fact both manifestations of the same effect.

Chapter One provides a detailed survey of studies showing meridional anisotrophy and considers the nature of its etiology and development. Chapter Two provides a review of the existing literature on the discrimination problem as evidenced in young children. The author argues that while meridional anisotrophy and poor oblique discrimination by young children appear to be related phenomena, it is possible that both are not manifestations of the same effect. The author tested this possibility by comparing the developmental course of poor oblique discrimination with the known developmental course of meridional anisotrophy.

Chapters Three through Six present four experiments in which the author tested young infants' ability to discriminate between mirror-image oblique stripes with their ability to discriminate between

vertical and horizontal ones, with the stripes above the threshold of acuity. In one experiment six week olds were tested; in the other three, 17-18 week old infants were tested using different variants of the habituation procedure.

The major finding of the research is that neither 6 week nor 17-18 week old infants, both of whom are known to show meridional anisotrophy, show evidence that a mirror-image oblique discrimination is more difficult than a discrimination between a vertical and horizontal. Furthermore, modification of the testing procedure, so that it more closely mimics a task in which children show difficulty discriminating mirror-image oblique lines, does not appear to affect 17-18 week olds discrimination performance.

In the final chapter, the author discusses the implications of the research findings. The author concludes that since infants known to show meridional anisotrophy do not show poor oblique discrimination, then it is probable that these two phenomena are not both manifestations of the same effect nor do they appear to be generated by the same underlying mechanism. The author also discusses the implications of the research findings for two cognitive theories which have been advanced to explain how children process obliquely oriented stimuli.

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INTRODUCTION

In general, for a wide variety of visual tasks, subjects perform more poorly when stimuli are oriented obliquely than when they are oriented vertically or horizontally. For example, acuity for lines oriented obliquely is less than that for lines oriented vertically or horizontally. Furthermore, even when stimuli are above the threshold of acuity, subjects discriminate vertical from horizontal orientations of a stimulus better than they discriminate between two oblique orientations, which are perpendicular to each other, that is mirror-images. These two phenomena are generally believed to be manifestations of one effect, generally termed the 'oblique effect'.

Interest in the oblique effect has been generated among investigators for a number of reasons. First, the effect is prevalent not only in human adults but also in children and several animal species. Second, the effect cannot be accounted for by optical properties of the eye. Third, it is believed that the generating site of at least one manifestation, meridional anisotrophy (reduced acuity for lines oriented obliquely), is in the visual cortex.

Since the oblique effect cannot be explained by optical properties of the eye and since it is apparent in many diverse tasks, it is generally agreed that this phenomenon results from some form of orientation asymmetry elsewhere in the visual system. This asymmetry causes an enhanced sensitivity in the visual system for vertical and horizontal contours. The bias for vertical and horizontal contours is attributed either to genetic factors or limited early visual experience. More specifically, neurons which respond to stimulus orientation might innately favor horizontal and vertical contours or might come to favor them because, early in life, the eye is exposed mainly to vertical and horizontal contours.

Only a few investigators have studied the oblique effect at an early stage of development; ie., during infancy. One of their findings is that infants as young as six weeks of age show reduced acuity for stripes oriented obliquely (meridional anisotrophy) (Cohen-Leehey, Moskowitz-Cook, Brill & Held, 1975). The authors interpret this finding as suggesting that the bias for vertical and horizontal contours in the visual system is genetically determined.

There are no data, however, on infants' ability to discriminate mirror-image oblique stripes, when the stripes are above the threshold of acuity. Although young infants show one manifestation of the oblique effect, meridional anisotrophy, they may not show the other, viz., more difficulty discriminating between mirror-image oblique orientations than between vertical and horizontal ones, when the stimuli are above the threshold of acuity. There is no reason to assume that these two phenomena are both manifestations of the oblique effect and consequently that they develop at the same time and are the product of the same underlying mechanism. Thus, the series of studies reported in this thesis attempted to determine whether young infants, known to show poorer acuity for obliquely oriented stripes than for vertically or horizontally oriented ones, also have difficulty discriminating between two mirror-image oblique stripes which are above the threshold of acuity.

CHAPTER ONE

THE OBLIQUE EFFECT IN DETECTION STUDIES

1.1 Historical Background

In 1925, Emsley reported that human subjects perceive lines more readily (ie. have better acuity) when the lines are oriented vertically and horizontally than when they are oriented obliquely. This effect persisted even when cylindrical lenses were used to optically correct the subject' vision in the oblique meridian. Consequently, Emsley termed this effect 'residual astigmatism' with the implication that its origin was different from that of normal astigmatism, which is purely optical in origin[1].

Residual astigmatism, which is now more commonly known as 'meridional anisotrophy', has since been noted with several measures of acuity; eg. grating acuity[2] (Higgins & Stultz, 1948; Leibowitz, 1953; Campbell, Kulikowsky & Levinson, 1966; Maffei & Campbell, 1970; Mitchell, Freeman & Millodot, 1973); vernier acuity[3] (Leibowitz, 1955) and minimal separable acuity[4] (Tyler & Mitchell, 1977).

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1. Astigmatism is an optical deficit which renders the power of the eye unequal in different meridians, with the meridian of maximal and minimal power perpendicular to each other. Consequently, the subject sees contours parallel to the non-astigmatic meridians more clearly than contours parallel to the astigmatic ones.
2. A stimulus traditionally used to measure acuity is a grating consisting of alternating light and dark stripes. Typically, the grating has a sinusoidal luminance profile, that is the luminance perpendicular to the stripes of the grating is modulated sinusoidally about a fixed mean level. The spatial frequency of a grating can be described as the number of whole cycles of contrasting areas (1 cycle

The finding of poorer acuity for oblique orientations however is not restricted to traditional methods of measuring acuity. On the contrary, it has been found repeatedly for humans in a variety of tasks, including setting lines to specified orientations. Perhaps the earliest report of poorer performance for oblique orientations was made by Jastrow in 1893 (cited in Appelle, 1972). Subjects, when required to reproduce visually presented lines or to set other lines to some specified orientation, showed a marked superiority in performance with stimuli oriented vertically or horizontally. Since that time, a number of studies have confirmed this result. Bouma & Andriessen (1968) asked subjects to align a dot to a perceived extension of a line segment, the orientation of which was varied. When the line was obliquely oriented, subject's accuracy in adjusting the dot was poorer; the standard deviation was 2.5 times greater than when the line was vertical or horizontal.

Similar findings have been reported when subjects are required to rotate a test line so that it appears parallel to a reference line. The variability in the subjects' settings is minimal when the reference

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= 1 light + 1 dark stripe) over some unit distance. The contrast between the light and dark stripes is known to be a function of the spatial frequency. Thus grating acuity can be determined in one of two ways: 1) presenting a grating of a certain spatial frequency and asking the subject to adjust the contrast of the grating until it can just be seen; 2) presenting a grating of a certain contrast and asking the subject to vary the spatial frequency until the grating can just be seen.

3. Vernier acuity is the threshold of perception of a break in the continuity of a contour.

4. Minimal separable acuity is the smallest separation between two lines which allows them to be perceived as distinct.

line is horizontal and maximal when it is oblique (Sulzer & Zener, 1953; Onley & Volkman, 1958; Andrews, 1965; 1967a; 1967b).

The type of results described above is not restricted to either the use of line stimuli or the use of the 'matching' paradigm. A similar perceptual bias for vertically and horizontally oriented stimuli has been demonstrated using circular test fields and measuring localization accuracy (Leibowitz, Meyers & Grant, 1955); using line or angle stabilized images (Craig & Lichtenstein, 1953; McFarland, 1968), and measuring critical flicker fusion frequency for different stimulus locations in the visual field (Foley, 1962). The results of these studies suggest that reduced acuity for obliquely oriented stimuli is definitely a persistent feature of orientation perception regardless of the stimuli or paradigm used.

In recent years, compelling evidence has been amassed which indicates that meridional anisotrophy cannot be accounted for by optical factors or eye movements. For example, small refractive errors are known to cause large decreases in the resolving power of the eye for gratings (Campbell & Green, 1965). Thus, if there is a slight refractive error along the oblique meridian, then one might find a preference for other meridians which are not oblique. Maximal optical correction for all orientations, however, does not eliminate anisotrophy (Mitchell, Freeman & Haegerstrom, 1973). Moreover, meridional anisotrophy is found even when interference fringes are projected directly onto the retina by a laser (Campbell & Kulikowsky, 1966; Mitchell, Freeman & Westheimer, 1967). Since this technique essentially bypasses the optics of the eye, it clearly rules astigmatism as a possible determinant of the effect.

Alternatively, it is possible that the distribution in the pattern of eye movements is not equal for different orientations, causing blurring in certain meridians due to the motion of the retinal image (Nachmias, 1960). Reduced acuity for obliquely oriented stimuli, however, persists even with brief exposure durations, less than 1 millisecond, during which no eye movements could occur (Higgins & Stultz, 1950).

Since both optical properties of the eye and eye movements have been eliminated as factors responsible for meridional anisotrophy, these findings suggest that the basis for the effect has to be sought somewhere else in the visual system.

1.2 Neurophysiological Mechanisms of Orientation Analysis

A number of attempts have been made to relate the psychophysical findings of meridional anisotrophy with neurophysiological mechanisms of orientation analysis. In general, studies of mammalian visual systems have established that the first level of the visual system which can detect changes in stimulus orientation is the striate cortex (area 17). Specifically, in cat and monkey, the receptive fields of striate neurons are composed of elongated excitatory and inhibitory areas which are oriented either horizontally, vertically or obliquely (Hubel & Wiesel, 1962; 1968). Consequently, these cells respond maximally to stimuli of a particular size, orientation and position (Hubel & Wiesel, 1959). This type of receptive field structure appears to be unique to neurons in the visual cortex (including area 17). Neurons in subcortical centers, eg. the lateral geniculate nucleus and superior colliculus, have receptive fields which are concentrically organized and thus do not respond to stimulus orientation (Hubel, 1959; Mohler & Wurtz, 1977).

Direct neurophysiological evidence for orientation selective neurons in man is of course lacking. There are perceptual data, however, which indicate that similar neural mechanisms, referred to as 'orientation selective channels or units', must exist. Furthermore, these data also indicate that the response properties of oblique units are somewhat different from those of vertical and horizontal units.

The most compelling data suggesting orientation selective channels in man, have been obtained using adaptation and masking grating techniques. Frequently, when a subject is shown a grating (referred to as an 'adapting' grating) the visibility of a different test grating, presented either simultaneously or successively, is reduced. In general, the ability of the adapting grating to affect the visibility of the test grating is assumed to reflect the extent to which the perception of each is dependent upon a common mechanism. Thus, if the sensitivity of a particular detecting mechanism is lowered by recent stimulation, then the contrast threshold[5] for other stimuli which depend on the same mechanism for perception will be raised.

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5. Traditionally, a psychophysical measure of acuity is obtained by asking the subject to increase the contrast of a grating until he can see it clearly. The amount of contrast between the light and dark lines of the grating which is necessary to see the grating is termed the 'contrast threshold'. The reciprocal of this contrast threshold defines 'contrast sensitivity' for a grating of that particular spatial frequency.

Data from several psychophysical studies suggest that the extent to which an adapting grating affects the visibility of a test grating is dependent on their respective orientations. For example, Gilinsky (1968) reports that the time required to perceive a test grating following exposure to an adapting grating (from here on refered to as 'duration threshold') is a function of both the orientation of the adapting grating and how long it is exposed. Typically, duration threshold increases when the subject is previously shown an identically oriented grating and this effect is most striking after a long adaptation time. In contrast, increasing adaptation time alone has little effect on subjects' duration threshold, when the orientations of the adapting and test gratings are different. In fact, under these conditions, duration threshold is the same as that found when the adapting stimulus is merely a blank field. Furchner and Young (1975) obtained similar results using a reaction time measure. When adapting and test gratings were the same orientation, subjects' reaction time for detecting the test grating was longer than when the adapting stimulus was a blank field. Similarly, this effect decreased as the time interval and orientation difference between the adapting and test stimuli increased. Since in both these studies, the visibility of the test grating was maximally affected when the orientations of the two gratings were the same, these results suggest that the perception of each grating was dependent upon a common mechanism - specifically a line detector which is orientation specific. Gilinsky suggests that line detectors in the human "... respond with decreased sensitivity to lines in those spatial directions with which they have been most strongly stimulated'. (Gilinsky, 1968, p.16).

A further demonstration of independent orientation channels in the human visual system has been shown by Campbell and Maffei (1970). Recording the occipital potential[6] evoked by gratings, they presented a vertical grating to one eye and varied the contrast of the grating. Subsequently, they derived a regression line by plotting the amplitude of the evoked potential against the grating contrast. A similar regression line was obtained for a horizontal grating. When the two orientations of the grating were presented simultaneously, one to each eye, the slope of the regression line was twice that found monocularly. These authors suggest that this result can be accounted for by the activation of two separate orientation selective channels whose activity ~~has~~ summed, thus increasing the amplitude of the evoked potential.

It appears, then, that the human visual system, like that of the cat and monkey, is composed of independent orientation selective channels. Other data, however, suggest that not all orientation channels respond in exactly the same fashion. Specifically, the orientation selective channel for oblique lines appears to be different from those for vertical and horizontal ones in both angular selectivity[7] and contrast threshold.

6. An occipital potential is measured from the surface of the skull and assesses the postsynaptic potentials induced in the visual cortex by a visual stimulus.

7. A given orientation selective neuron and presumably an orientation selective channel responds maximally to a particular stimulus orientation. Such neurons, however, also respond to a range of orientations on either side of the maximal one. The broadness or narrowness of this range defines the 'angular selectivity' of a given neuron or channel. Channels which respond maximally or near

On the basis of measurements of contrast threshold, Campbell & Kulikowsky (1966) concluded that the angular selectivity of vertical channels is narrower than that for oblique ones. They demonstrated that the contrast threshold for a vertical test grating is affected by the presence of a supra-threshold grating only when the two gratings have nearly the same orientation. This finding is consistent with the adaptation effect reported by Gilinsky (1968) and Furchner & Young, 1975). In the Campbell & Kulikowsky investigation, the increase in contrast threshold is maximal when the two gratings have the same orientation but the effectiveness of the background grating is decreased by half when the orientation of the two gratings differs by 12°. In contrast, when an oblique test grating is used, the effectiveness of the background is reduced by half only when the angle between the two gratings is at least 15°. Thus angular selectivity for the oblique orientation is 25% poorer than that for the vertical orientation, 12° versus 15°. From other lines of evidence, these authors dismiss optical factors as being the basis for the difference between the two orientations. Angular selectivity, they suggest is poorer for the oblique orientation because of a specific property of the visual system which they conclude is composed of several overlapping orientations channels separated by 12°-15°[8].

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maximally to a broad range of orientations are refered to as having 'poor angular selectivity'. Alternatively, those which have 'good angular selectivity' respond maximally or near maximally to a narrow range of orientations and are called 'finely tuned'.

8. Tests of vertical gratings using other techniques suggest the degree of separation between orientation channels is less than that reported by Campbell and Kulikowsky (1966). With the adaptation

In a further study, Campbell & Maffei (1970) measured contrast threshold for vertical, horizontal and oblique gratings from occipital evoked potentials. Specifically, they plotted the amplitude of the occipital potential at a number of different contrasts and derived a regression line for each orientation separately. Based on the derived regression lines, they obtained thresholds by extrapolating to the zero-voltage amplitude which crosses the contrast axis at the psychophysical contrast threshold. While the contrast threshold for the vertical and horizontal gratings were the same, the contrast threshold for the oblique grating was .3 log units less. In other words, to elicit an evoked potential of a given amplitude, contrast in the oblique meridians must be increased by .3 log units relative to the vertical and horizontal meridians. Thus the orientation selective channel for oblique lines differs from those for vertical and horizontal ones not only in angular selectivity but also in contrast threshold.

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method, the subject is first exposed to an adapting grating and the change in contrast threshold of a subsequently exposed vertical test grating is determined. Blakemore & Nachmias (1971) and Gilinsky (1968) have reported that the effect of the adapting grating on the threshold of the vertical test grating is reduced by half when the two gratings differ by 7°. A more sensitive estimate of orientation selectivity has been obtained with the subthreshold summation technique. With this technique, the effectiveness of a <u>subthreshold</u> background grating in increasing the contrast threshold of a vertical test grating is reduced by half for an angle of 3° between the two gratings (Kulikowsky, Abadi & King-Smith, 1973). Thus it now appears that the visual system is most likely composed of orientation selective channels which are separated by 3° of visual angle rather than 12° or 7°, as estimated by masking and adaptation methods. It should be noted, however, that except for the Campbell and Kulikowsky (1966) masking experiment, only vertical test gratings have been used.

In summary, the evidence suggests not only that there are orientation selective channels in man but also that there exists an orientation asymmetry among these units; oblique units having poorer angular selectivity and higher contrast threshold. Thus, the preference for vertical and horizontal orientations reported in the behavioural literature seems to correspond nicely with a similar neurological bias in the orientation analyzing system.

1.2.1 <u>Site of Neurological Mechanisms Underlying Meridional Anisotrophy</u>

Both the psychophysical and electrophysiological data have provided us with clues concerning the basis of meridional anisotrophy. As has been previously noted, optical factors have been ruled out by demonstrations of meridional anisotrophy, using gratings formed by interference fringe techniques, which by-pass any optical irregularities of the eye (Campbell & Kulikowsky, 1966; Mitchell, Freeman & Westheimer, 1967). Second, meridional anisotrophy has been found even with brief exposures eliminating eye movements as a critical factor (Higgins & Stultz, 1950). Third, several investigators have reported anisotrophy among orientation selective channels with oblique units being different from vertical and horizontal ones in angular selectivity and contrast threshold. (Campbell & Kulikowsky, 1966; Gilinsky, 1968; Campbell & Maffei, 1970).

Recently, Maffei & Campbell (1970) using evoked potential techniques, have reported anisotrophy in evoked potentials recorded from the occipital scalp but not from the retina. Specifically, they found that the occipital potentials evoked by vertical and horizontal gratings were similar but the amplitude evoked by an oblique grating was lower than that for vertical and horizontal ones. Using the same stimuli and recording the potential from the retina, they found no difference in the amplitude for the three orientations. This result suggests that any difference in the perception of the three orientations is not retinally based. They concluded that '... the electrophysiological correlates of the psychophysical observations, that the resolving power for the oblique orientation is less than that of the vertical and horizontal is due to a mechanism which lies between the site of origin of the electroretinogram and the evoked potential of the visual cortex..." (Maffei & Campbell, 1970, p.387).

We know however that the visual evoked potential recorded from the occipital scalp arises from both cortical and subcortical structures (Kapura, 1971, cited in Haith, 1976). Since the evoked potential varies with the orientation of a grating, then at least part must arise from neurons that are highly sensitive to orientation. Furthermore, since the primary visual cortex is known to contain neurons that are highly sensitive to orientation it seems likely that the neurons in the striate cortex are involved. Considered together, then, the psychophysical and electrophysiological data implicate post-retinal neural structures, most likely striate neurons, as the generating site of meridional anisotrophy.

Evidence from primate studies appear to support the notion that meridional anisotrophy is most likely mediated via striate neurons. Baurer, Owens, Thomas, MacDonald & Held (1978) have recently reported that normally-reared monkeys show meridional anisotrophy. In their study, grating resolution was assessed by requiring subjects to adjust the orientation of a bar to match the orientation of a grating upon which it was superimposed. The time needed to make a correct match was longer for the oblique than for the vertical and horizontal orientations at the higher spatial frequencies tested[9]. This finding is not only consistent with the psychophysical data from humans (Cammisa, Blake & Lima, 1977) but also is consistent with a recent report of anisotrophy among monkey striate neurons. Specifically, Mansfield (1974), recording single unit activity in the monkey striate cortex, has reported that neurons with foveal receptive fields are 'tuned' mainly for vertical and horizontal rather than oblique stimulus orientations. Thus, at least in the monkey, there appears to be a good correspondence between meridional anisotrophy and the existence of anisotrophy among striate neurons.

In recent years, indirect evidence has made it possible to locate more precisely the site of meridional anisotrophy. Although meridional anisotrophy is a persistent feature of orientation perception, it is more likely to occur under some conditions than others. First, when measured with grating stimuli, orientation variations in contrast sensitivity for different orientations of a grating are more pronounced at higher spatial frequencies. (Campbell &

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9. A grating or grid refers to stimulus composed of alternating black and white stripes. Spatial frequency can be described as the number of cycles of contrasting areas (1 cycle = 1 black and 1 white stripe) over some unit distance. It is usually defined as the number of cycles of a grating which subtend 1 degree of visual angle of the eye of the observer. The higher the spatial frequency, the narrower the stripes; the lower the spatial frequency, the wider the stripes.

Kulikowsky, 1966; Berkeley et al., 1975; Cammisa, Lima & Blake, 1977). Second, meridional anisotrophy is greatest when stimuli are presented on the fovea and falls off dramatically with peripheral viewing (Berkeley et al., 1975). Finally, the effect appears only when a grating is stationary or flickered at low rates of temporal modulation (Cammisa, Blake & Lima, 1977).

We now know that the visual nervous systems of cat and monkey (Cleland et al., 1971a; Gouras, 1968, 1969; Ikeda & Wright, 1974; Poggio et al., 1977) are composed of at least two classes of neurones, termed sustained and transient, which are distinguishable on the basis of their spatial selectivity and retinal distribution. In particular, sustained cells respond to higher spatial frequencies than do transient cells and are more numerous within the foveal area. Furthermore, these sustained units respond only at low rates of temporal modulation of the stimulus. These sustained characteristics appear to match the optimal stimulus conditions for meridional anisotrophy. Thus, these data suggest that sustained-type mechanisms in human vision, the existence of which has been established psychophysically by others (Kulikowsky & Tolhurst, 1973; Tolhurst, 1973) are the principle mediator of meridional anisotrophy.

1.3 Theoretical Explanations of Meridional Anisotrophy

It is generally agreed that meridional anisotrophy results from some form of neural asymmetry which leads to enhanced sensitivity for vertically and horizontally oriented stimuli. Physiologically, this asymmetry would be expressed by more cells which respond to vertical and horizontal orientations than to oblique ones. In contrast, there is debate, concerning the contribution of early visual experience in establishing this neural asymmetry. Physiologically, a bias in orientation units could arise either by atrophication of cells responding to oblique meridians due to deprivation or by conversion of cells originally intended to respond to obliques, to ones tuned to verticals and horizontals (Freeman & Thibos, 1973).

That early visual experience can modify the orientational selectivity of cortical neurons has been well documented in cats. For example, raising an immature animal in a 'meridian limited' environment, that is one in which the animal is exposed only to stripes of a particular orientation, produces a loss in cells which would normally respond to the non-exposed orientations (Hirsh & Spinelli, 1970; 1971; 1972; Blackmore & Cooper, 1970; Blakemore & Mitchell, 1973). Furthermore, early selective exposure to stripes of a single orientation also results in reduced acuity for contours orthogonal to those that were present in the animal's early visual environment (Muir & Mitchell, 1973). The results of these experiments, then, indicate that, the orientational properties of cortical neurons (whether it be changes in the optimal orientation to which they respond or in the precision with which they are tuned) can be modified during a time at which the cortex is developing (in cat, the susceptible period begins during the fourth week and ends about three months postpartem (Hubel & Wiesel, 1970). Furthermore, they suggest that the physiological changes produced are accompanied by concordant alterations in the animal's perceptual abilities.

Recent evidence from humans with high astigmatism suggests that human neural organization may also be influenced in a similar way (Mitchell, Freeman, Millodot & Haegerstrom, 1973). High astigmats (+ or - 4 D) provide a good model for the study of neural plasticity in humans; due to their optical error, their visual experience is restricted, that is they see contours parallel to the non-astigmatic meridians more clearly than contours parallel to the astigmatic ones. Furthermore, evidence suggests that in most cases of high astigmatism, the condition was present since birth so that the visual experience of these subjects would have been 'restricted' until the optical error was corrected (Hirsch, 1963; Duke-Elder, 1969). Thus, if astigmatism is present early, the lack of exposure to well defined stimuli along the axis of astigmatism might affect neuronal maturation. Consequently, cortical centers could be modified to process detail for the non-astigmatic meridians better than for the astigmatic ones.

Mitchell and Wilkinson (1974) have demonstrated that for high astigmats (astigmatism along the horizontal axis) who remained optically uncorrected until age ten, the contrast sensitivity for a horizontal grating was lower than for a vertical one. This effect persisted even when the optical error was corrected with lenses or when sinusoidal interference fringes were formed directly on the retina. This result is quite different from those obtained from normal subjects who typically show no difference in contrast sensitivity between these stimulus orientations[10]. Based on the correlation between these

10. It should be noted that similar psychophysical findings have been obtained using other indices of grating acuity. Freeman, Mitchell &

findings and those from the animal studies (Muir & Mitchell, 1973) Mitchell suggests that these differences in the resolution of stimulus orientation are a conseqeunce of changes induced in the neural organization of the visual system; specifically, changes induced by distorted visual input provided in early life by uncorrected astigmatism.

Freeman and Thibos (1973) have provided direct electrophysiological evidence supporting Mitchell's claim of a neural correlate to meridional resolution differences. Measuring high astigmats' occipital evoked potential to gratings in different orientations, they found the amplitude was depressed when the gratings were presented along the astigmatic meridian. However, the evoked potential was identical to that of normal subjects when the gratings were presented along the non-astigmatic meridians. Again, maximal optical correction did not affect this pattern of results. These findings suggest that the locus of the asymmetry between the astigmatic and non-astigmatic meridians, is neural in origin. Furthermore, they also indicate that early optical error, causing selective visual deprivation, can effect neural changes that are specific and lasting. Clinical evidence appears to support the notion that asymmetries in the evoked potential results from limited deprivation. Specifically,

Millodot (1972) report that the highest spatial frequency (ie., maximum number of lines) that can be resolved for different orientations of a grating varys as a function of astigmatism; a lower spatial frequency for orientations along the astigmatic axis; a higher spatial frequency for the non-astigmatic axis.

children with reduced resolution due to visual disuse or prolonged suppression have abnormally depressed evoked potentials (Lombroso, Duffy & Robb, 1969).

Based on the findings of astigmatic subjects, Mitchell and Wilkinson (1974) proposed that the meridional anisotrophy observed in normal subjects, might be similarly induced by certain asymmetries in early visual input. Initial support for this hypothesis can be found in a study by Annis & Frost (1973). Specifically, they argue that superior resolution for horizontal and vertical contours is the result of being raised in a 'carpentered world'; that is one in which vertical and horizontal contours predominate. Annis & Frost report that a group of Cree Indians, raised in a relatively non-carpentered environment, failed to show statistically significant anisotrophy; while a group of Euro-Canadians, raised in typical North American homes, did. Based on these findings, Annis and Frost argued that the enhanced sensitivity of the visual system to vertical and horizontal contours might be determined at an early stage of development by the environmental predominance of such contours. It is possible, however, that the difference between these two ethnic groups is due to a genetic component and not to environmental differences. This possibility cannot be ruled out since Annis and Frost did not test Cree Indians who were raised in a carpentered environment.

It is now apparent that the nature of the carpentered environment is not sufficient to account for cross-cultural differences in meridional anisotrophy. For example, Timney and Muir (1976) report striking differences in the magnitude of meridional anisotrophy shown by Caucasian and Chinese subjects, even though both groups were raised in essentially the same type of carpentered environment. Specifically, they report that the magnitude of anisotrophy is significantly less for Chinese compared with Caucasian subjects. Furthermore, within the Caucasian group, the magnitude of anisotrophy varied substantially. Considered together, these findings suggest that the nature of the visual world is not the only contributing factor in establishing meridional anisotrophy. On the contrary, it now appears that a genetic component might be the prepotent factor.

Additional support for a genetic component may be found in a recent study by Leehey, Cook, Brill & Held (1975) which suggests that infants between 5-6 weeks of age show meridional anisotrophy. In this study, infants saw pairs of gratings of the same spatial frequency, one grating was either vertically or horizontally oriented; the other obliquely (45^{o} or 135^{o}). Four spatial frequencies were tested, .75, 1.5, 3, 6 and 12 cycles /deg. During a given trial an observer looked at the infant's head and eye movements through a peephole and judged which member of the pair the infant looked at longer. For each spatial frequency, the percentage of trials during which the infant fixated the vertical or horizontal grating longer than the oblique, was calculated. Infants looked significantly longer at the vertical or horizontal gratings than at the oblique grating - but usually only at a particular spatial frequency (from here on refered to as 'peak preference'). This looking preference, however declined at both higher and lower spatial frequencies. These authors argued that if infants' acuity for oblique gratings was less than their acuity for vertical or horizontal ones then one would expect, at spatial frequencies near or at the threshold of acuity, infants would look longer at the vertical or horizontal gratings because they see them more clearly than the otherwise equivalent oblique gratings.

Initial support for this inference may be found in the decline in looking preference at spatial frequencies higher and lower than that at which the peak preference was found. It is suggested that the decline at higher frequencies indicates the infant's decreasing ability to resolve either orientation of the grating. Similarly, the decline at lower frequencies indicates the increasing ability to resolve both gratings.

In a recent replication, Gwiadza, Brill, Mohindra & Held (1977) report a good correlation between the acuity thresholds for vertical gratings and the spatial frequency at which the peak preference for vertical or horizontal gratings over obliques was found by Cohen-Leehey et al. These findings further support Cohen-Leehey's interpretation that the peak preference for vertical or horizontals over obliques results from an acuity difference between these orientations.

Considered together; then these data suggest that infants as young as six weeks show meridional anisotrophy. Furthermore, the occurance of meridional anisotrophy at such a young age suggests that this phenomenon is most likely due to a neural asymmetry which is genetically rather than experientially induced.

CHAPTER TWO

THE OBLIQUE EFFECT IN DISCRIMINATION STUDIES

Consideration of the results from several discrimination studies demonstrates that meridional anisotrophy may be only one manifestation of the oblique effect. For example, several investigators have shown that children even as old as eight years, have more difficulty discriminating between mirror-image oblique lines than between vertical and horizontal ones, even though the lines are above the threshold of acuity (Rudel & Teuber, 1963; Over & Over, 1967; Bryant, 1969; 1973).

In general, three types of recognition tasks have been used to test childrens' discrimination of mirror-image oblique lines: simultaneous discrimination, 2 alternative forced choice, and successive same/different discrimination. With some of these tasks, interpretation of the findings can be somewhat ambiguous, since it is not clear what causes the child's difficulty - the nature of the procedure or the nature of the stimuli (ie. that they are oriented obliquely). Before one can be confident that the child, in fact, shows more difficulty discriminating between mirror-image oblique lines (here on refered to as 'mirror-image confusion of oblique lines') than between vertical and horizontal ones, it is first necessary to re-examine the procedures which have demonstrated this difficulty in the child.

2.1 Simultaneous Discrimination

One of the most common methods used to test mirror-image confusion is 'simultaneous discrimination'. In this task, a pair of stimuli is shown simultaneously. One member of the pair is designated 'correct'; the other 'incorrect'. At first, the child is required to choose the 'correct' member of the pair by guessing. On subsequent trials, after being given feedback about the correctness of his choice, the child is required to continue to choose the 'correct' member of the pair. The pair is repeatedly shown until the child reaches a criterion of learning; specifically, until he chooses the 'correct' member of the pair on 9 out of 10 consecutive trials.[11]

Typically, with this procedure, young children (3 1/2 to 8 1/2 years) show more difficulty learning to pick the 'correct' line when shown pairs of mirror-image oblique lines (ie. \ vs /). Compared with other pairs of lines, (ie. \ vs —; or | vs \), children require more trials to learn the discrimination and often fail to learn the discrimination at all (Rudel & Teuber, 1963; Jeffrey, 1966; Over & Over, 1967).

In a recent study, however, Harris, Le Tendre & Bishop (1974) using the same procedure and stimuli, did not find mirror-image confusion of oblique lines among similarly aged children. The only

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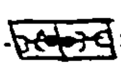
11. A sample of the instructions given in a simultaneous discrimination task is the following:
"I am going to show you two cards; one of them is 'right' and one is 'wrong'. At first you can only guess which is right, but after you guessed, I will tell you whether you guessed right or wrong. After that you must always pick the card which is 'right' and never the card which is 'wrong'.

Rudel & Teuber, 1963, p.893

feature distinguishing this study and those reporting mirror-image confusion is the nature of the alignment of the pairs of lines. In the studies which found mirror-image confusion, the stimuli were in 'horizontal alignment', that is one beside the other (eg. \ /). In Harris et al.'s study, which did not find mirror-image confusion, the stimuli were in 'vertical alignment', that is one on top of the other (eg. ). Thus, it appears that the childrens' difficulty in discriminating mirror-image oblique lines may be due to the nature of the procedure; specifically horizontal alignment of the stimuli.

That stimulus alignment can induce errors in the discrimination of stimulus orientation, has been dramatically demonstrated by Barroso and Braine (1974). In their study, they showed 3-5 year old children pictures of real objects, eg. a girl, tree, clown's face, etc. A standard figure was always positioned in one window of a pair of frames and the frames were either aligned horizontally or aligned vertically. (eg.  or ). Children were required to place in the other window a 'placement' figure so that it matched the orientation of the standard. For one group, the placement figure was the same object as the standard; for the other, it was a different realistic figure.

Only when the frames were horizontally aligned did the children make left-right reversal errors, that is place the stimulus so that it was the mirror-image of the standard (eg.  not ). Likewise, when the frames were vertically aligned, they made more inversion errors (eg.  not ). More surprisingly, children made the same pattern of orientation errors even when the stimulus pairs were not identical. Thus, mirror-image confusion of these stimuli did not appear to be caused by the intrinsic nature of the stimuli but rather by the axis of alignment of the stimuli.

Barrosa and Braine suggest that the child does not make an absolute judgement of orientation - 'judging the orientation of each figure in relation to a spatial framework', but makes a relative judgement of orientation - 'judging orientation of each figure in relation to each other'. The child's strategy, then, is to match the two figures by placing comparable parts of the figures close to each other, ie., tops with tops. Consider what would happen when the standard is turned on its side and the frames are horizontally aligned (eg. ). If the child is using the strategy outlined above, he will place the top of the placement figure next to the top of the standard - consequently making a left-right reversal error (eg. ). However, when the same standard is positioned in frames which are vertically aligned, a correct response will be made. The child will place the top of the placement figure directly underneath the top of the standard. Thus the two figures will be oriented the same way (eg. )[12] A similar analysis would also explain inversion errors when the frames are aligned vertically.

The studies which have found mirror-image confusion of oblique lines, using the simultaneous discrimination method, assumed that

12. Alignment effects are not only found with children. Two studies of adults (Wolff, 1971; Sekuler & Houlihan, 1968) investigated reaction time for same/different judgements under various conditions of stimulus placement and orientation. Subjects' reaction times were longer for left-right reversals of the stimulus when they were aligned horizontally. Similarly times were longer for an inversion of the stimulus when they were aligned vertically. These results suggest that the child's strategy may also be used by adult.

problems in learning to discriminate between left and right oblique lines resulted from a perceived identity between the correct orientation and the incorrect orientation of the stimulus. The findings of Barroso and Braine (1974) however, suggest that the difficulty may be more a consequence of the way the lines were aligned and not the perceived identity of the different orientations.

2.2 Two Alternative Forced Choice

The child's difficulty discriminating mirror-image oblique lines in a simultaneous discrimination task may reflect an artefact in the procedure rather than a lack of the ability being tested. Mirror-image confusion of oblique lines, however, has also been found using a '2 alternative forced choice' procedure. This is a procedure which is not susceptible to the alignment effects ~~just~~ described.

In a 2 alternative forced choice task, the child is shown a standard for a pre-determined period of time. He is told to look at it and remember it. The standard is then removed and sometime later[13], two stimuli, including a duplicate and mirror-image rotation of the standard are presented simultaneously. The child must pick the 'choice' stimulus which is the same as the standard previously shown.

13. The length of exposure to the standard and the length of delay before showing the choice stimuli vary from study to study. Typically, the standard has been shown for 5 or 15 seconds (Bryant, 1969; Harris et al., 1974; Corballis & Zalik, 1977; Mandler & Stein, 1977) while the inter-trial intervals have varied from 5 to 90 seconds (Bryant, 1969; Mandler & Stein, 1977; Over & Over, 1967). Since differences in the findings of these studies do not appear to be attributable to these time parameters, I will not concentrate on these procedural differences.

For example, the child is asked "...which line is like the one you just saw?... 'top' or 'bottom'." (Harris et al., 1974, p.262).

In general, children as young as 4 years 7 months and as old as 7 years have difficulty in discriminating mirror-image oblique lines in a two alternative forced choice task. They tend to make more errors with the mirror-image oblique lines than with non-mirror-image oblique lines (ie. | vs — ; or \ vs /), regardless of whether the 'choice' lines are horizontally or vertically aligned. (Bryant, 1969; Harris et al., 1974; Corballis & Zalik, 1977; Bryant, 1973). In a two alternative forced choice task, then alignment of the stimuli is not the critical parameter which induces orientation errors.

In all these studies, children were not given feedback about the correctness of their choice. Furthermore, they were not informed that the dimension relevant to solving the task was orientation. Caldwell and Hall (1969) have suggested that without explicit instruction, young children do not include differences in orientation in their definition of 'different'. It is possible then that children would make fewer discrimination errors if they were given feedback. Indeed, children's ability to discriminate left and right oblique lines can be markedly improved when they are given pre-training which is designed to teach the child orienting responses to figures oriented in different directions (Jeffrey, 1966). Furthermore, when feedback is given in a 2 alternative forced choice procedure, 6 year old children do not make significantly more errors with mirror-image oblique lines than with vertical and horizontal lines (Over & Over, 1969).

In the studies which report mirror-image confusion of oblique lines, discrimination between the major-orthogonals (eg. \ vs —) and between a major orthogonal and oblique (eg. \ vs /) were also tested. Children showed no evidence that these discriminations were problematic, even though they were not given feedback and were not informed that orientation was the relevant dimension for solving the problem. Feedback may become a critical factor only when the two stimuli to be discriminated are independently judged as similar. For example, when children under ten are asked to pick from several rotations of a standard geometric shape, one which they think is most similar to the standard, they typically pick the mirror-image rotation (Oyama & Sato, 1975). By age 10, however, there is a shift in judgements of similarity, such that a 45° rotation of the standard is now judged most similar.

Consider what this would mean for the discrimination of mirror-image oblique lines in a two alternative forced choice task. The child is asked to pick the 'one which is <u>like</u> the one he just saw'. If the child interprets this instruction to mean '<u>most similar</u>', then according to the data on judgements of similarity, the child, who regards the mirror-image rotation as most similar to the standard, should pick the left-right reversal as often as the standard. In fact, children under 8 yars pick the correct choice line (duplicate of the standard) only about 50% of the time (Harris et al., 1974; Bryant, 1969). It is not surprising that when children are induced to attend to the orientation of the stimuli through feedback and/or pre-training, their performance with mirror-image pairs improves (Jeffrey, 1966; Caldwell & Hall, 1969).

2.3 Successive Same/Different Discrimination

It appears that childrens' inability to discriminate mirror-image oblique lines may be due to the nature of the measure which has been used to test mirror-image confusion. Stimulus alignment may cause mirror-image confusion of oblique lines in a simultaneous discrimination task; while lack of feedback or inattention to orientation as a dimension may induce orientation errors in a two alternative forced choice paradigm. Both these procedures, then tend to make interpretation of the findings somewhat ambiguous.

A third type of recognition task which has been used to test mirror-image confusion in young children is 'successive same/different discrimination'. In general, children are first given a 'training' phase during which they learn the stimulus and presumably encode its characteristics. Following the training phase, they are given a recognition test which includes at least three stimuli; the standard (eg. \), a mirror-image rotation of the standard (eg. /) and a non-mirror-image rotation of the standard (eg. \/).

Two variations of this task have been used. Stein and Mandler (1974) allowed the child 15 seconds to look at the standard and verbally describe it. The standard was then removed and 20 seconds later the child was asked to verbally recall the standard he had seen. Immediately, thereafter, he was successively presented the standard and three rotations of the standard including the mirror-image rotation. The child's task was to say whether the stimulus on each retention trial was the 'same' or 'different' from the standard he previously saw.

In the procedure used by Rudel and Teuber (1963), children were first trained to discriminate a pair of lines (eg. \ /). One member of the pair was designated 'right' (eg. \ ); the other 'wrong' (eg. /). Each member of the pair was repeatedly shown until the child reached a criterion of learning. Following the training phase, the child was successively shown six figures, including the 'correct' orientaton and a mirror-image rotation of the standard. The child was required to say whether the stimulus presented on each trial was 'right' or 'wrong'.

Regardless of the variation used, 5 and 7 1/2 year old children make more errors with mirror-image oblique lines, that is they call the mirror-image rotation of the standard 'same' or 'right' in the recognition test (Stein & Mandler, 1974; Rudel & Teuber, 1963). In fact, children make errors only with mirror-image rotation of the standard.

Unlike other procedures, performance does not improve when the children are told that orientation is the relevant dimension for solving the task; when they are pretrained on a matching-to-sample task; when they are required to describe the standard while viewing it or required to recall the standard after it is removed (Stein & Mandler, 1974). Thus, children show no evidence of being able to discriminate mirror-image lines as easily as vertical from horizontal ones regardless of which variant of the procedure is used.

In summary, three types of recognition tasks have been used to test mirror-image confusion in young children. Although children show difficulty in learning to discriminate mirror-image oblique lines in all three tasks, the nature of some procedures makes interpretation of the findings ambiguous. Several methodological features of the 'simultaneous discrimination' and '2 alternative forced choice' procedures, ie., stimulus alignment, lack of feedback, etc, have been suggested as possible determinants of the child's mirror-image confusion of oblique lines. The findings from the 'successive same/different discrimination' tasks, however, do provide compelling evidence that young children have more difficulty discriminating mirror-image oblique lines than vertical from horizontal ones and that their difficulty can only be attributed to the nature of the stimuli and not the nature of the procedure used.[14]

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14. Bryant (1969) has reported that young children show the same difficulty discriminating between oblique lines even when they are not the exact mirror-images. This finding suggests that the critical factor underlying mirror-image confusion of oblique lines is the orientation of the stimuli rather than their mirror-image nature. A recent study by Corballis & Zalik (1977) however, using the same task, reports that discrimination of oblique lines improves significantly when the lines are not exact mirror-images. At present, the issue regarding the relative contribution of these two factors, (ie., obliqueness of the stimulus or mirror-image nature) in producing mirror-image confusion of oblique lines remains unsettled. Thus, for purposes of this discussion both obliqueness and the mirror-image nature of the stimuli will be considered as factors contributing to childrens' mirror-image confusion of oblique lines.

2.4 Rational for Thesis

The coincidence of reduced acuity for obliquely oriented stimuli (meridional anisotrophy) and childrens' difficulty discriminating mirror-image oblique lines has led researchers to assume that one factor, acuity, in some way explains the other, discrimination. Specifically, Appelle (1972) suggests that both phenomena not only represent the 'oblique effect' but also are generated by the same underlying mechanism.

It is generally agreed that meridional anisotrophy results from some form of asymmetry in the visual system for processing the orientation of a stimulus. This asymmetry would cause an enhanced sensitivity in the visual system for vertical and horizontal contours. On the basis of several lines of converging evidence, it has been suggested that the generating site of meridional anisotrophy lies in post-retinal structures, most likely in the striate cortex (Campbell & Kulikowsky, 1966; Mitchell, Freeman & Westheimer, 1967; Gilinsky, 1967; Maffei & Campbell, 1970). Furthermore, the evidence also strongly suggests that this phenomenon is due to an orientational asymmetry which is genetically rather than experientially induced (Timney & Muir, 1976; Cohen-Leehey, Moskowitz-Cook, Brill & Held, 1975).

It is likely that poor discrimination of obliquely oriented stimuli may also be generated by some kind of cortical mechanism since we know that the visual cortex is necessary for the discrimination of stimulus orientation. For example, monkeys with ablations of the striate cortex and subsequent retrograde degeneration of the lateral geniculate nucleus can not discriminate vertical from horizontal stripes (Weiskrantz, 1963).

Although it is generally assumed that the mechanism responsible for poor oblique discrimination is the same as that responsible for meridional anisotrophy, it is possible that both phenomena develop at different times and are attributable to the different underlying mechanisms. While reduced acuity for obliquely oriented stimuli has been repeatedly found for humans, the effect is never large and may play no direct role in ordinary perception ie. discrimination of obliquely oriented stimuli (Timney & Muir, 1976).

In the present series of studies, I tested orientation discrimination in infants, who are known to have poorer acuity for obliquely oriented stripes than for vertical and horizontal ones. I expected that if the acuity and discrimination phenomena were generated by the same mechanism, then infants who show meridional anisotrophy would also show more difficulty discriminating between mirror-image oblique stripes than vertical from horizontal ones. Alternatively, if the two phenomena are not generated from the same mechanism, then infants, know to show meridional anisotrophy may not show difficulty discriminating mirror-image oblique stripes.

CHAPTER THREE

EXPERIMENT 1

While reduced acuity for obliquely oriented stripes (meridional anisotrophy) has been inferred in infants as young as six weeks (Cohen-Leehey, Moskowitz-Cook, Brill & Held, 1975), there is no data to show if similarly aged infants find it more difficult to discriminate between mirror-image oblique stripes than between vertical and horizontal ones when the stripes are above the threshold of acuity. Before studying this issue of orientation discrimination in six week old infants, it was first necessary to determine a stripe width (spatial frequency) which is above the threshold value for vertical, horizontal, left oblique and right oblique stripes.

Traditionally, studies of acuity have tested young infants' acuity for vertically oriented stripes (Miranda, 1970; Gorman, Cagan & Gellis, 1959; Dayton et al., 1964). The findings of Fantz, Ordy and Udelf (1962) suggest that the threshold for vertical stripes is .75 cy/deg for 4-6 week old infants. Recently, Teller et al. (1974) and Gwiazda et al. (1977) have tested acuity not only for vertical stripes but also for oblique stripes, using modifications of the preferential looking technique developed by Fantz (1965; 1967). This technique is premised on the fact that infants spontaneously fixate patterns longer than homogeneous stimuli. Thus, the narrowest striped stimulus which the infant will consistently fixate longer than a grey field provides a measure of acuity. Both Teller (1974) and Gwiadza et al. (1977) report no significant difference in the thresholds of acuity for vertical and oblique stripes for 6 week old infants. It is possible that this finding may be due to the technique used, ie., a striped stimulus paired with a grey field. Specifically at a given frequency, vertical and oblique stripes may both be visible and therefore both be fixated longer than a grey field. One of the orientations, however, may in fact appear clearer than the other. Such a difference, then, might go undetected with a pattern vs. grey technique.

The findings of a recent study by Leehey et al. (1975), using a pattern vs. pattern technique, suggest that the threshold of acuity for oblique stripes is, in fact, lower than that for vertical stripes. On each trial, Leehey et al. presented infants two striped circles of the same width; one circle was oriented either vertically or horizontally; the other was oriented obliquely to the right or obliquely to the left. For each spatial frequency tested, they determined which of the two circles the infants looked at longer. Four stripe widths (spatial frequencies) were tested, .75, 1.5, 3, 6, and 12 cy/deg.

These authors reasoned that if infants' acuity for oblique stripes were less than their acuity for vertical and horizontal ones, then at spatial frequencies near or at the threshold of acuity, the infants would see the vertical or horizontal stripes more clearly than the oblique stripes and thus should look longer at the vertical or horizontal stripes than at the oblique stripes. At higher spatial frequencies, infants would not be able to resolve any of the stripes and hence should be as likely to look at oblique stripes as at vertical or horizontal ones. Similarly, at lower spatial frequencies the infants would be able to resolve the stripes in any orientation and hence should not look significantly longer at the vertical or horizontal stripes. Thus, it is possible to determine the threshold for oblique stripes by noting the frequency at which infants look longer at the vertical or horizontal stripes than at the oblique stripes.

For 14-50 week old infants, Leehey et al.'s expectations were borne out; that is at a particular spatial frequency, infants looked longer at the vertical or horizontal stripes than at the oblique stripes. This preference declined at higher and lower spatial frequencies. For 6-13 week old infants, however, the data are incomplete. Infants showed maximum looking preference to vertical or horizontal stripes at the lowest frequency tested (.75 cy/deg.) Like older infants, this looking preference declined at higher spatial frequencies. Since the spatial frequency at which maximum preference for vertical or horizontal stripes was the lowest frequency tested for the 6-13 week old infants, it is not possible to know if there would be a decline in preference at lower frequencies. Consequently, it is not possible to derive from Leehey et al.'s data, the spatial frequency which would be above the threshold of acuity for stripes oriented in major-orthogonal (| or –) and oblique-orthogonal (\ or /) orientations at six weeks[15].

15. In a recent replication of Leehey et al's. (1975) study, Gwiadza et al. (1977) tested 7-13 week old infants with a spatial frequency lower than .75 cy/deg (.38 cy/deg.). Infants showed no significant looking preference for vertical or horizontal stripes at this frequency. The youngest age tested, however, was older than the infants in the present study, that is 7 weeks compared to 6 weeks.

In the present study, three stripe widths (.25, .5 and .75 cy/deg) were chosen for testing on the basis of Leehey et al.'s (1975) data for 6-13 week old infants. Two spatial frequencies lower than .75 cy/deg (.25, .5 cy/deg), as opposed to one were chosen to be tested to insure that at least one of these stripe widths was well above the threshold of acuity for the oblique orientations. On each trial, I showed infants pairs of circles, one being a grey circle, the other being a striped circle varied in spatial frequency and orientation (ie. | , — , \ or /). It has been well documented that infants look longer at patterned rather than homogeneous stimuli (Fantz, 1965). Thus, I expected that most infants would look longer at the striped than at the grey circle if the stripes were seen clearly, ie., if the spatial frequency used was well above threshold. Since I was not interested in finding the threshold of acuity but only interested in being sure all orientations were well above threshold, it was not necessary to use the stripe versus stripe technique used by Leehey et al. (1975).

METHOD

Subjects

The subjects were 10 full-term six week old infants (6 males; 4 females) with no known birth abnormalities. Their mean age was 43.8 days (range 35-49 days). Four other infants were excluded from the study because of crying and fussing.

Stimuli

The stimuli were four circles with black and white stripes

Figure 1. Schematic drawing of apparatus.

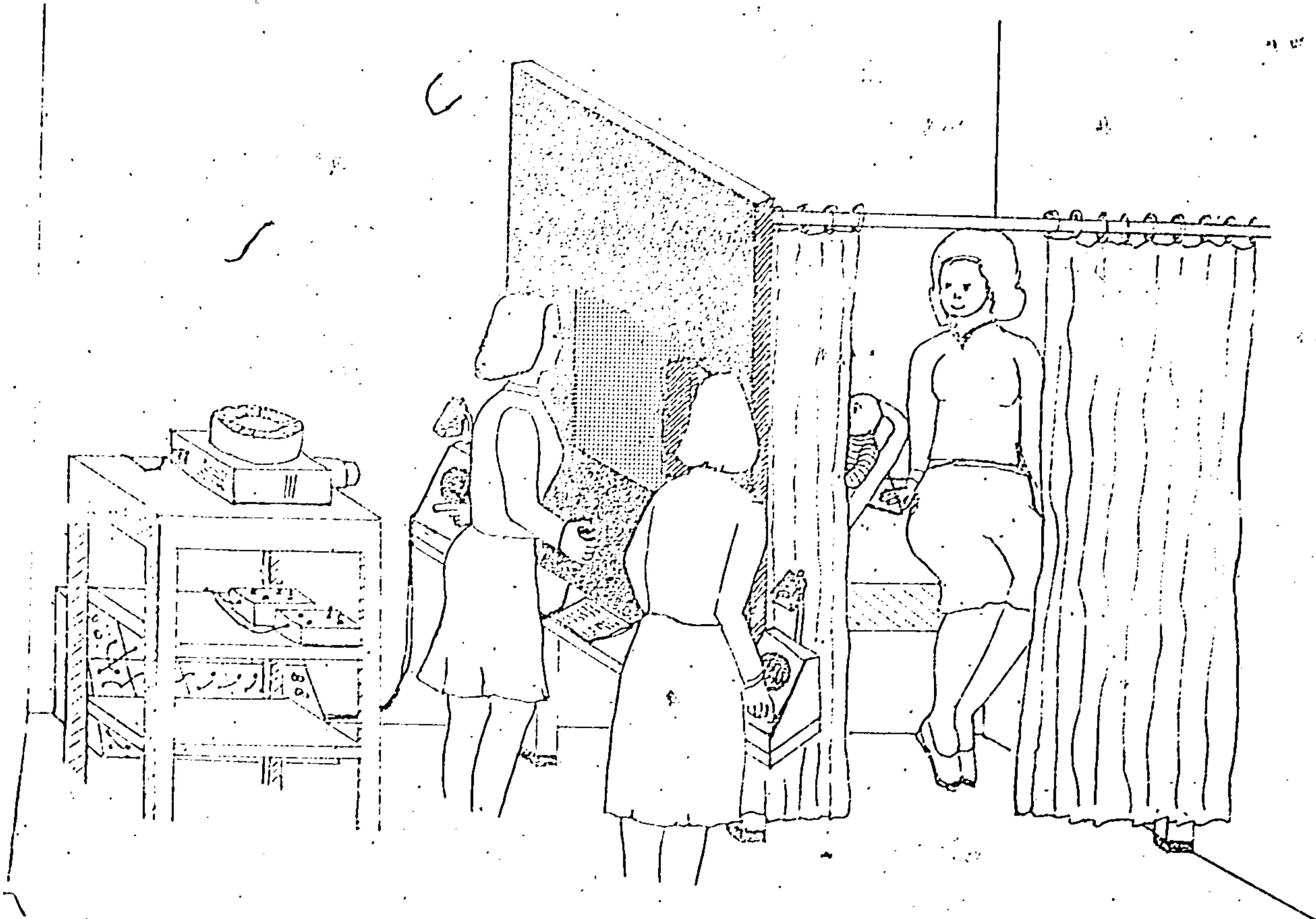


Figure 1

oriented at either 0°, 90°, 45° or 135°. The stripes were either 1.46 cm., .73 cm., or .49 cm. wide (.25, .5, .75 cy/deg.) Each circle was on a dark grey background and subtended 20° of visual angle. Each circle was paired with a circle with stripes of a higher frequency (more than 12 cy/deg) which gave the appearance of a grey circle (here on refered to as 'grey circle') and which at the same time matched the stripes of the lower frequency in overall brightness. Each pair was separated by 23° of visual angle. In all, there were 24 pairs of stimuli, including counterbalancing of the side on which the higher frequency circle occurred (3 frequencies x 4 orientations x 2 sides). Each infant was shown the 24 pairs in a randomized order.

Apparatus

The apparatus (shown in Figure 1) consisted of a black panel which was mounted at the end of a table and from which a rectangular window (45cm x 32.5cm) was removed. The window was covered by a piece of rear-projection screen and served as the viewing screen.

The infant sat in an infant seat positioned so that his head was 45 cm in front of, and aligned with the midline of the viewing screen. Slides of the stimuli were rear-projected onto the viewing screen by a Kodak Carousel projector situated behind the screen.

Two peepholes, .525 cm in diameter, were positioned 25 cm to the right and left of the center of the screen.

Two observers were located behind and beside the screen. One had two cumulative timers; the other observer had four. There was a black panel at the rear right edge of the screen which prevented the first observer from viewing the screen and consequently from knowing what was being shown.

Procedure

After the experimenter explained the procedure to the mother and obtained permission, she placed the infant in the infant seat. The mother sat behind the infant and was instructed to comfort the infant with a pacifier, pats, or talking if necessary. Prior to testing, the experimenter turned off the room lights, turned on white noise, and presented a female face on the screen to attract the infant's attention.

The technique used was a modification of Teller et al.'s (1974) two alternative preferential looking technique. On each trial, a pair of stimuli was shown for 15 seconds. During a trial, each observer activated one of the timers when the infant started fixating the circle on the left, as judged by the reflection of the circle on his pupil. Whenever she judged the infant to have looked away, she released the timer. Similarly, she activated the second timer whenever she judged that the infant looked at the circle on the right. At the end of the trial, the projector automatically advanced to the next slide and a new trial began after 2 seconds.

After every two trials an orienting stimulus, an interesting form in the center of the screen, was shown for 15 seconds. The orienting stimulus served the purpose of maintaining the infant's interest during testing and allowed the first observer time to record the fixation times from the previous two trials. Note the first observer recorded fixation times on every trial; while the second observer recorded times only on every other trial.

Data Analysis

The fixation times used in the calculations were those recorded by the first observer, since she recorded fixations on every trial. For any given pair of stimuli, the mean length of an infant's fixation on each member of the pair, across the two counterbalanced trials, was calculated and compared. For example, if an infant looked 8 seconds at the striped circle when it was on the left and 4 seconds when it was on the right, then the mean length of fixation on the striped circle would be 6 seconds for that pair. A similar calculation was done for the grey circle of the pair. The mean fixation values for the striped and grey circles were subsequently compared for that infant.

It has been well demonstrated that infants preferentially fixate patterned rather than homogeneous stimuli (Fantz, 1965). Thus if the striped circle was above the threshold of acuity, the infant should fixate it longer than the grey circle.

To estimate whether the two observer's were reliably recording the same behaviour, Pearson Product Moment correlations were calculated separately for the fixation times recorded for eight infants.[16] Each correlation was based on twelve trials. A correlation was calculated separately for times recorded for looking to the left and to the right circle of the pair. The mean correlation was .95 for the left circle (range: .77-.99) and .91 for the right circle (Range: .76-.99).

16. Inter-observer reliability was not calculated for two of the ten infants because the second observer's records were incomplete.

Table 1. Individual infant's fixation on each member of an acuity pair in Experiment 1.

Table 1

Subjects		0°	grey	180°	grey	45°	grey	135°	grey
		Spatial frequency (.25 cy/deg)							
		acuity pair							
1		11.6	0	5.2	4.4	8.6	0	9.2	0
2		5.4	1.6	5.9	5.3	5.8	4.9	5.2	3.3
3		5.8	4.2	5.4	5.1	5.7	1.7	5	3.1
4		4.2	4.4*	12	0	10.9	0	2.03	1.3
5		11.2	0	11	0	9.8	0	5.9	5.7
6		10.2	.5	10.8	0	5.2	4.4	11.2	0
7		8.8	0	7.6	0	8.2	0	4.9	1.8
8		12.7	0	7.1	0	10.7	0	9.5	0
9		1.3	6.1*	12.8	0	8.1	0	6.2	2.7
10		7.3	.7	5.1	1.7	4.5	4.3	7.4	1
	$\bar{X}$ =	7.85	1.75	8.29	1.65	7.75	1.53	6.65	1.8
	sd =	3.68	2.28	2.04	2.34	2.33	2.14	2.71	1.84
		Spatial frequency (.5 cy/deg)							
1		10.1	.1	10.4	.1	10.8	0	11.9	0
2		5.5	6.2*	8.9	8.7	6.1	5.4	6.2	5.1
3		5.2	5.3	5.5	0	3.8	4.2*	9.6	0
4		7.1	0	4.2	.2	9.3	.2	9.6	0
5		4.2	5.4*	4.2	4.3*	6.9	4.4	11.2	.4
6		4.4	5.5*	6.5	0	5.2	3.2	6	3.8
7		2.3	6.4*	5.8	0	5.3	2.3	9.5	0
8		3.7	5.1*	8.9	0	9.4	.4	4.6	0
9		.3	2	.1	4.9*	2.8	1.8	0	1.4*
10		5.1	.6	9.1	.7	3.7	.4	2.4	2.6
	$\bar{X}$ =	4.79	3.66	6.36	1.89	6.33	2.23	7.1	1.33
	sd =	2.63	2.63	3.10	3.04	2.72	1.99	3.93	1.88

Table 1 (cont'd).

Subjects	Spatial frequency (.75 cy/deg)							
	acuity pair							
	0°	grey	180°	grey	45°	grey	135°	grey
1	8.8	.4	9.6	.7	7.1	1.6	7.1	.4
2	4.4	5.5*	5.3	5.8	4.4	3.3	5.2	4.9
3	0	1*	3.6	5.3*	7.3	0	9.2	.5
4	3.1	3	4.5	4	2.2	2.1	10.8	0
5	11.6	0	7	1.9	2.6	1.9	10.9	0
6	5.7	3.5	6.2	3.6	4.5	4.3	10.8	.1
7	1.5	4.4*	10.9	0	7.8	.05	5.5	1.7
8	10.05	.4	3.7	0	9.4	.4	11.6	0
9	2.4	1.7	.5	2.2*	3	4.9*	6.3	.6
10	6.5	.05	6.1	0	6	.4	4.4	5.3*
$\bar{X}$ =	5.65	1.99	5.74	2.35	5.43	1.9	7.88	1.35
sd =	3.82	1.98	3.01	2.22	2.46	1.78	3.33	2.04

*indicates that the infant looked longer at the grey circle than at the grid.

RESULTS AND DISCUSSION

The data are shown in Table 1. Inspection of the group data show that infants looked longer at the striped circle than the grey circle for each orientation and each spatial frequency. This finding suggests that six week old infants see the stripes as different from grey even at the .75 cy/deg frequency.

Inspection of individual infant's performance across the three spatial frequencies, however, indicates that the lowest number of misses (looking longer at the grey circle than at the striped circle) occurred at .25 cy/deg compared with .5 and .75 cy/deg; 2, 9, and 7 misses, respectively.

Thus, I chose a stripe width of 1.46 cm (.25 cy/deg) as the above threshold value for the subsequent experiment, since at this frequency nearly all the babies looked longer at the striped than at the grey circle.

EXPERIMENT 2

Since 'meridional anisotrophy' has been inferred in infants as young as six weeks of age, the present study was aimed at determining whether similarly aged infants have more difficulty discriminating between mirror-image oblique stripes than between vertical and horizontal ones.

Although it is relatively easy to demonstrate discrimination in older infants, it can prove a difficult task in infants as young as six weeks of age. For example, discrimination performance within a group of young infants may be quite variable. This variability, more often than not, seems to reflect the influence of a number of extraneous factors, ie., state, time of last feeding, maturity of the oculo-motor system, etc., rather than the ability being tested. To minimize this variability, it is important to choose a procedure appropriate to the age being tested. Specifically, the technique used must be 1) sensitive enough to allow unambiguous interpretation of the data; 2) be an accurate measure of the ability being tested.

In general, three techniques have been used to test young infants' ability to discriminate different stimuli: spontaneous visual preference, familiarization and habituation. Although each of these procedures is effective with older infants, they do not appear to be equally effective in assessing the young infant's discrimination capabilities. For example, infants as young as six weeks appear to be able to discriminate an upright face from an inverted one, when tested with habituation (McGurk, 1970). In contrast, infants do not show this ability until at least 16 1/2 weeks of age when tested with the familiarization method (Fagan, 1972). It is necessary, then, to consider the drawbacks and advantages of each of these procedures for testing young infants.

In a spontaneous visual preference procedure, infants are shown (either simultaneously or successively) two stimuli, differing from each other along some dimension, and the length of time the infant looks at each of the two stimuli is recorded. A difference in the length of time the infant looks at two stimuli is considered evidence of his ability to discriminate between them.

Although this technique, developed by Fantz (reviewed in Fantz, Fagan & Miranda, 1975), has been successively used with newborns to demonstrate discrimination of such stimulus features as curvature (Fantz, 1963); number of elements (Miranda & Fantz, 1971) and orientation (Slater & Sykes, 1977), it is still relatively insensitive for assessing young infants' discrimination capabilities. For example, investigators assume that if the infant looks longer at one stimulus than at the other, he sees the two stimuli as different in some way. It does not follow, however, that if the infant looks equally long at both stimuli he does not perceive them as different. He may see them as different but find them equally attractive to look at. Interpretation of the findings then will be unambiguous only when the infant's visual response to the two stimuli is different. In the absence of such a difference the findings are uninterpretable.

Traditionally, after exposure to a stimulus, a change in an infant's looking from the familiar stimulus to a novel one, has been used to indicate pattern recognition or discrimination. This shift in looking preference is commonly termed 'response to novelty'. Two experimental methods have typically been employed to test infants' response to novelty.

In one, the familiarization technique developed by Fagan (1970), infants are simultaneously shown two identical stimuli for a specified length of time. Following this familiarization phase, infants are given two test trials one with the familiar stimulus on one side and a novel stimulus on the other; the second with the positions of the stimuli reversed. If the infant fixates the novel stimulus more than the familiar one, this shift is taken to indicate his ability to discriminate the two stimuli.

It is now apparent that the familiarization method is not appropriate for assessing young infants' discrimination abilities. There are several reasons for the limitations of this technique with young infants. First, infants younger than six weeks scan in quite a limited fashion (Salapatek & Kessen, 1966; Leahy, 1976); also, young infants tend to show more position bias in their looking than do older infants (Harris, 1975). Consider what this would mean when the infant is simultaneously shown novel and familiar stimuli on a test trial. Due to the immaturity of his scanning patterns, he would be unlikely to compare (look back and forth) and assess the two stimuli simultaneously, and therefore be unlikely to look longer at the novel stimulus. Failure to find more looking at the novel stimulus would reflect the infant's position bias, that he looks at the stimulus on one side regardless of its nature, and not his inability to discriminate the two stimuli. Even if he did eventually shift his eyes to the second stimulus, the pre-determined length of the trial might impose a ceiling effect on his fixation to the second stimulus, yielding no difference in fixation to the two stimuli.

Second, unlike 5-6 month old infants (Fagan, 1974), younger infants may prefer to look at a familiar stimulus rather than at a novel one under these circumstances. The findings of Hunter and Ames (1975) suggest that when the familiarization period is interrupted before an habituation criterion (specified decline in visual fixation) is met, most young infants will look longer at the familiar stimulus than at a novel one. It appears that in order for some young infants to respond to novelty, they must first habituate. This can be problematic, since some infants might show a prefereence for familiarity because they have not habituated, and other infants a preference for novelty. Failure to find response to novelty in a group analysis then, would be due to the mixture of the infants' responses and not necessarily their inability to discriminte the two stimuli. The familiarization technique, then appears not to be the method of choice for accessing the discriminative capacities of young infants.

A second procedure which has been used to test response to novelty is the 'habituation-test' procedure which developed from Sokolov's (1963, 1969) observations of the orienting reflex. Traditionally in the habituation method, the infant is repeatedly shown a single stimulus for a fixed number of trials. Following this habituation phase, the infant is given test trials in which the novel and habituated stimuli are presented successively. An increase in the infant's fixation to the novel stimulus compared with the habituated one is considered a measure of his ability to disriminate them.

The rationale underlying the habituation test procedure is the following. When the same stimulus is repeatedly shown, an infant's attention to it will decline or habituate (Jeffrey & Cohen, 1971). During this time, the infant is assumed to be encoding a representation of the characteristics of the stimulus. Following habituation, when a new stimulus is presented, a comparison is made between the new information which is currently being encoded and the memory trace which has formed during habituation. Increase in the infant's attention when a novel stimulus is shown reflects a mismatch between the memory trace and the current information and thus the infant's ability to discriminate the two stimuli (Cohen, 1973; Cohen & Gelber, 1975).

This method has been successively used with four week old infants to demonstrate discrimination of form (Milewski, 1978) and with two week olds and even newborns, to demonstrate discrimination of checkerboard patterns (Black, 1976; Friedman, 1972). Although the habituation method appears to be a very sensitive technique for assessing discrimination abilities in young infants, it is not without difficulties when the number of habituation trials and length of each trial are determined by the experimenter. For example, investigators assume that a certain number of habituation trials given the infant is adequate to allow him to encode the characteristics of the stimulus. For some infants, the number of trials chosen will be sufficient, however, for others it will not. For those infants who have not habituated in the number of trials provided, performance on the post-test will not be a reliable measure of their ability to discriminate the stimuli. Cohen & Gelber (1975) suggest that the most reliable measure of discrimination will be produced only when the novel stimuli are presented after each infant reaches his own criterion of habituation.

A second difficulty arises when the length of the trial is determined by the experimenter. This can be problematic in two ways. First, the infant may never look at the stimulus during a trial because he does not notice it. The recorded fixation time on such a trial would be zero. This time value would be misrepresentative since it would not indicate how long the infant would have looked if he noticed the stimulus was present. Second, if the infant is still looking at the stimulus when the trial ends, the recorded length of fixation would also be an inaccurate measure of his fixation since he might have looked much longer if given the opportunity. To ensure that the recorded fixation time is an accurate one, Cohen (1973) suggests that the trial begin when the infant starts looking at the stimulus and end when he looks away. Thus, a better procedure, one developed simultaneously by Cohen (1972) and Horowitz, Paden & Self (1972) is the 'infant control' habituation technique. In the infant control version, trial length and number of habituation trials are determined by the infant and not the experimenter.

Although the 'infant-control' habituation procedure is a viable technique for assessing young infant's discriminative capacities, interpretations of the findings can be ambiguous if the infant looks equally long at the novel and habituated stimuli. Failure to find response to novelty would not necessarily indicate that the infant cannot discriminate the two stimuli - he may just not have habituated or the procedure may have been too long and he may have been tired. One way of distinguishing between these possibilites is to include a second novel stimulus in the post-test, one which you know apriori the infant can discriminate from the habituated stimulus. If the infant looks longer at the second novel stimulus than at the habituated one, then he has truly habituated; if not the infant has either not habituated or is tired.

Thus, I tested orientation discrimination in 5-6 week old infants using the infant control 'habituation-test' procedure. I showed infants stripes in one orientation until their looking declined to a criterion of habituation and then presented stripes oriented perpendicularly to the original ones and an 8 x 8 checkerboard. I considered an increase in looking to the new orientation of the stripes to indicate discrimination between the habituated and novel orientations of the stripes.

METHOD

Subjects

The subjects were 32 full-term 5-6 week old infants (16 females; 16 males) with no known birth abnormalities. Their mean age was 45 days (range: 39-50 days). Thirty-one other infants were also tested but did not complete the procedure because they fussed, cried or slept. Data from four additional infants were also excluded because they did not show more looking at the 8 x 8 checkerboard in the post-test than at the stripes at the end of habituation (see below).

Stimuli

There were five stimuli -- an 8 x 8 black and white ckeckerboard and four circles with black and white stripes oriented either at 0°, 90°, 135°, or 45°. The stripes were 1.46 cm wide (.25 cycles/deg), the width shown in Experiment 1 to be well above threshold for infants of this age. The 8 x 8 checkerboard differed from the stripes in amount of contour (182.5 cm vs. 160.85 cm) and in area (224 sq cm vs. 193.66 sq cm).

All stimuli were presented one at a time in the center of the field and subtended 20° of visual arc.

Apparatus

The apparatus was similar to that described in Experiment 1, except each observer had a timer to record the length of fixations and a button to advance the slides. Slides advanced only when both observers had pressed their buttons.

Procedure

As in Experiment 1 an experimenter placed the infant in the infant seat so that the infant's eyes were 45 cm in front of the screen. Before testing, the experimenter turned off the room lights, turned on white noise and presented a female face on the screen to attract the infant's attention.

The technique used was a modification of the infant control habituation procedure used by Horowitz, Paden, Bhana & Self (1972). During a trial, each observer started a cumulative timer when she judged that the infant looked at the stimulus. When she judged the infant to have looked away, she stopped the timer, recorded the time, and pressed the button to advance the slide. Slides advanced only when both observers judged that fixation had ended. Thus, the infant's looking started the trial; cessation of looking ended the trial. For each baby I calculated agreement between the observers judgements of fixation by Pearson Product Moment correlation. The mean correlation was .98 (Range: .91-.99).

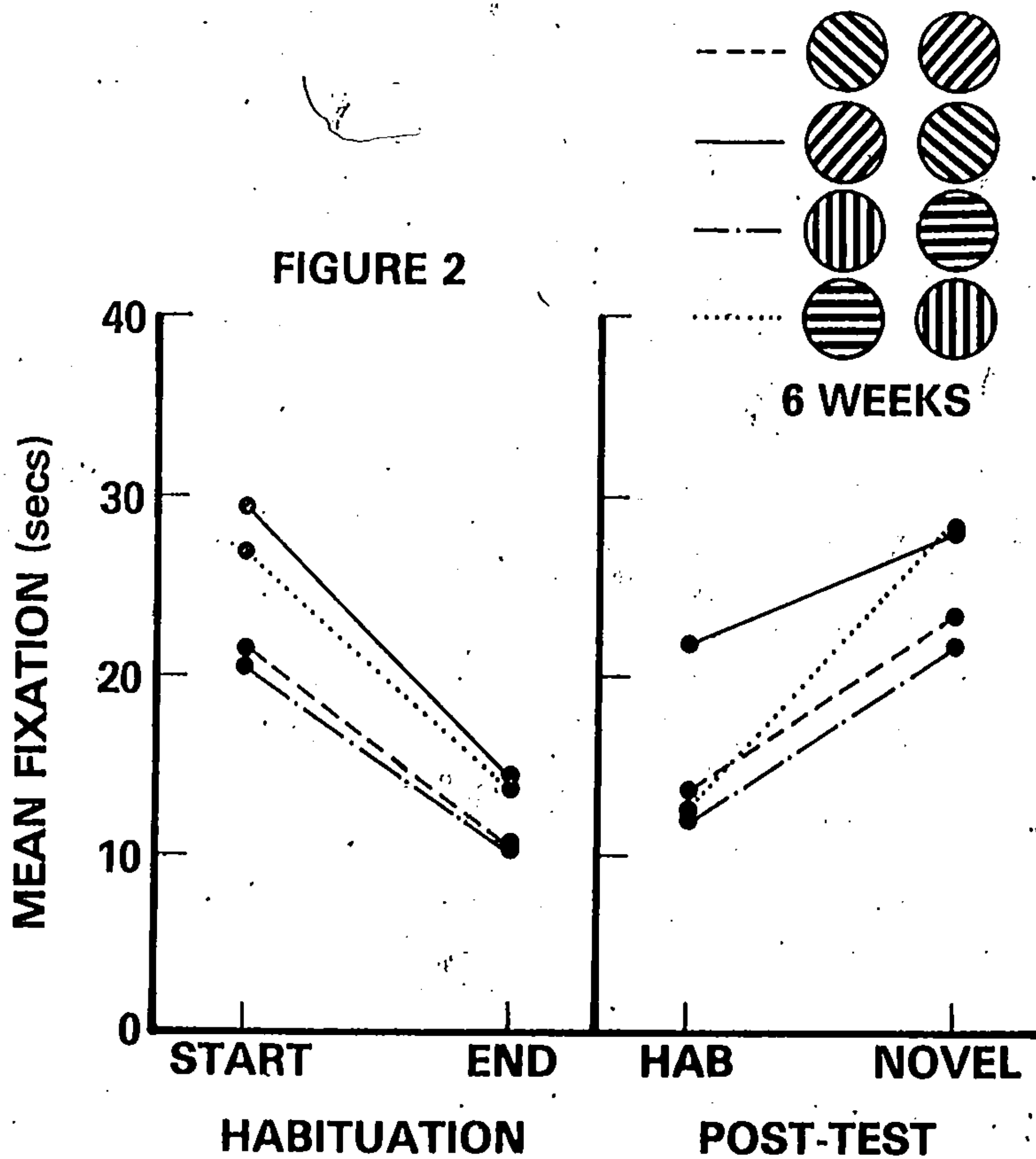
Infants were randomly assigned to one of four habituation groups. Each group was habituated to a different orientation of the stripes; vertical, horizontal, left oblique or right oblique.

Before habituation, the infant was given a pretest with three stimuli: stripes in the orientation to be habituated (A); stripes oriented perpendicularly to the ones to be habituated (B); and an 8 x 8 checkerboard (C). Each stimulus was presented twice in either an ABCCBA or BACCAB order, with these two orders counterbalanced within each group. This ordering was used so that decreases in infants' looking over trials would be likely to affect all stimuli equally.

Following the pretest, the infant was shown one orientation of the stripes (A) repeatedly until his looking fell to the criterion. After the criterion of habituation was met, each infant was shown the stripes for an additional trial to insure habituation. The criterion of habituation was two sets of three consecutive trials (eg., if set 1 = trials, 8, 9, 10; then set 2 = 9, 10, 11) during which the infant's mean fixation time was less than half of his mean fixation time on the first three habituation trials. Note that the minimum number of trials required to reach criterion would be 7.

Figure 2. Mean length of infants' fixation during habituation and post-test in Experiment 2. Vertical habituation group represented by (—•—); horizontal group by (· · · ·); left oblique group (- - -) and right oblique group by (——). For points representing the start of habituation, each infant contributed his mean fixation on the first three habituation trials; for points representing the end of habituation, each infant contributed his mean fixation on the second set of criterion trials; for points representing the post-test, each infant contributed the mean of his fixation on the two trials for the novel and habituated orientations, respectively.

FIGURE 2


6 WEEKS
MEAN FIXATION (secs)
40
30
20
10
0
START
END
HAB
NOVEL
HABITUATION
POST-TEST

After habituation, the infant was given a post-test that was identical to the pretest. Longer looking at the checkerboard in the post-test than at the stripes at the end of habituation, was taken to indicate that the infant had truly habituated. Based on other findings (Fantz, Ordy & Udelf (1962); Brennan, Ames & Moore, (1966) I expected that an infant of six weeks would look longer at the checkerboard since it differed from the stripes in several ways. Failure to find recovery to the checkerboard would imply that either the infant had not habituated or that he was tired. The data of four infants were excluded from the data analysis because they did not show the expected recovery to the checkerboard.

RESULTS

The data were analysed in three parts: post-test data; habituation data and pre-test data. All time data were transformed to natural logarithms to insure homogeneity of variance among the four groups' data (Winer, 1971). The raw data are shown in the figures.

Post-test data

To find out if an infant looked longer at the novel orientation of the stripes than at the habituated one, I first obtained a score for each stimulus: for each stimulus in the post-test, I calculated the mean of the fixation times recorded by the two observers on each trial and summed the means across the two trials for that stimulus.

In all groups, infants looked significantly longer at the novel than at the habituated orientation of the stripes. The post-test data are shown in Figure 2. A 4 (orientation groups) x 2 (habituated-novel orientation of the stripes) ANOVA with repeated measures showed a significant difference between the length of infants' looking at the novel and habituated stimuli ($F_{1,\ 28} = 16.74$, $p < .005$). No significant between group effect or stimulus x group interaction was found.

Habituation Data

I compared the four habituation groups on four measures of habituation:

1) the number of trials an infant took to reach the criterion; 2) the criterion of habituation, ie., half the infant's mean looking on the first three habituation trials; 3) the level of looking at the end of habituation, ie., the mean level of the infant's looking during the second set of criterion trials; 4) the total length of time the infant looked during habituation. (Note that each of these measures was based on the larger of the values recorded by the two observers.) One way ANOVA's showed the four groups did not differ on any of these measures.

Pre-Test Data

To determine if infants initially preferred to look longer at one stimulus than at another, I first obtained a score for each stimulus in the pretest in the same way as in the post-test. For these analyses the data from the vertical and horizontal habituation groups were collapsed since these infants were presented both vertical and horizontal stripes in the pre-test. Similarly the data from the left and right oblique habituation groups were collapsed for the same reasons. These two sets of data were analysed separately by two one-way ANOVAs with repeated measures. The analysis showed no significant difference in the time infants looked at these stimuli.

Figure 3. Schematic drawing of a circle with stripes oriented obliquely to the left.

Figure 3

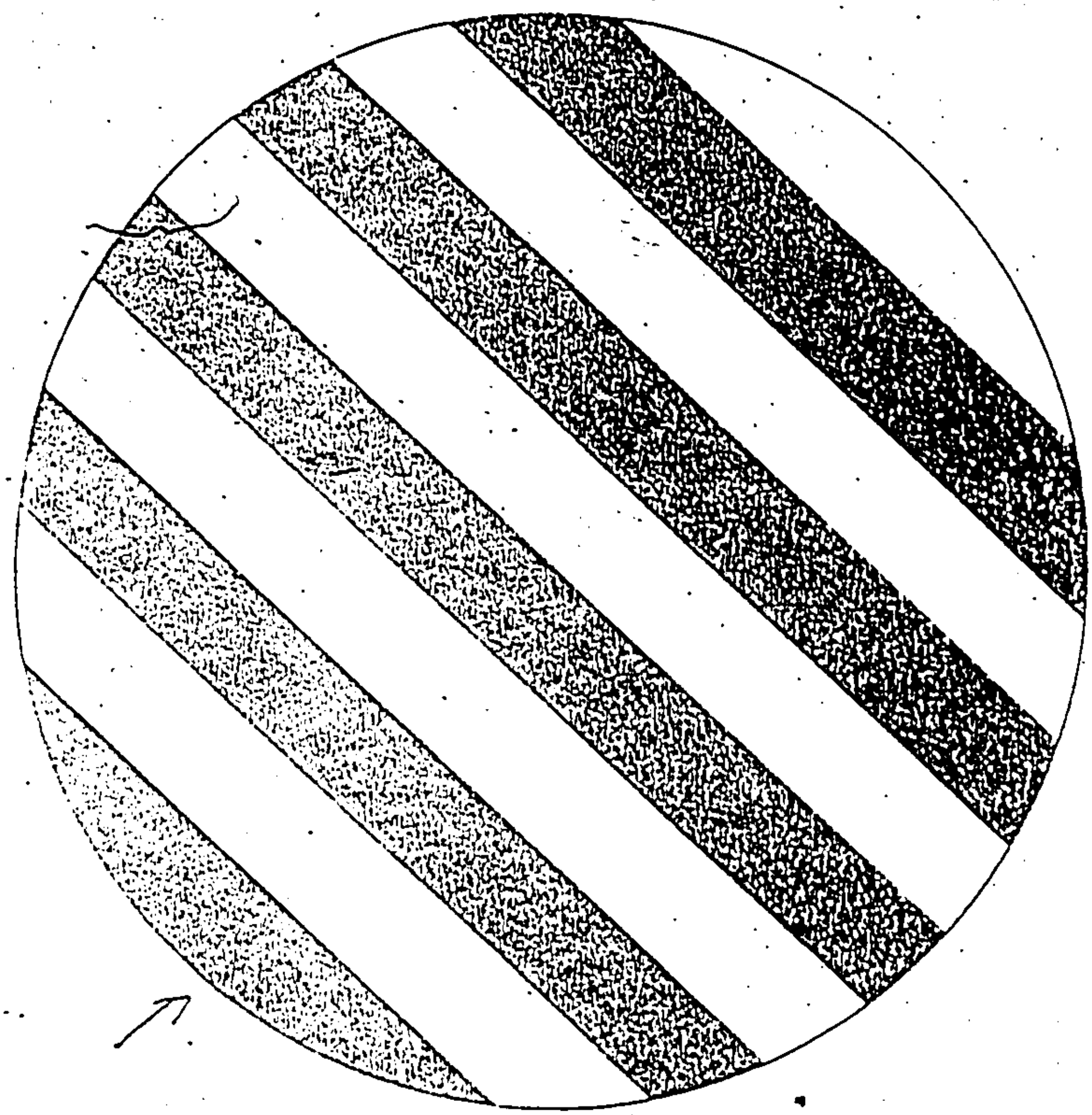
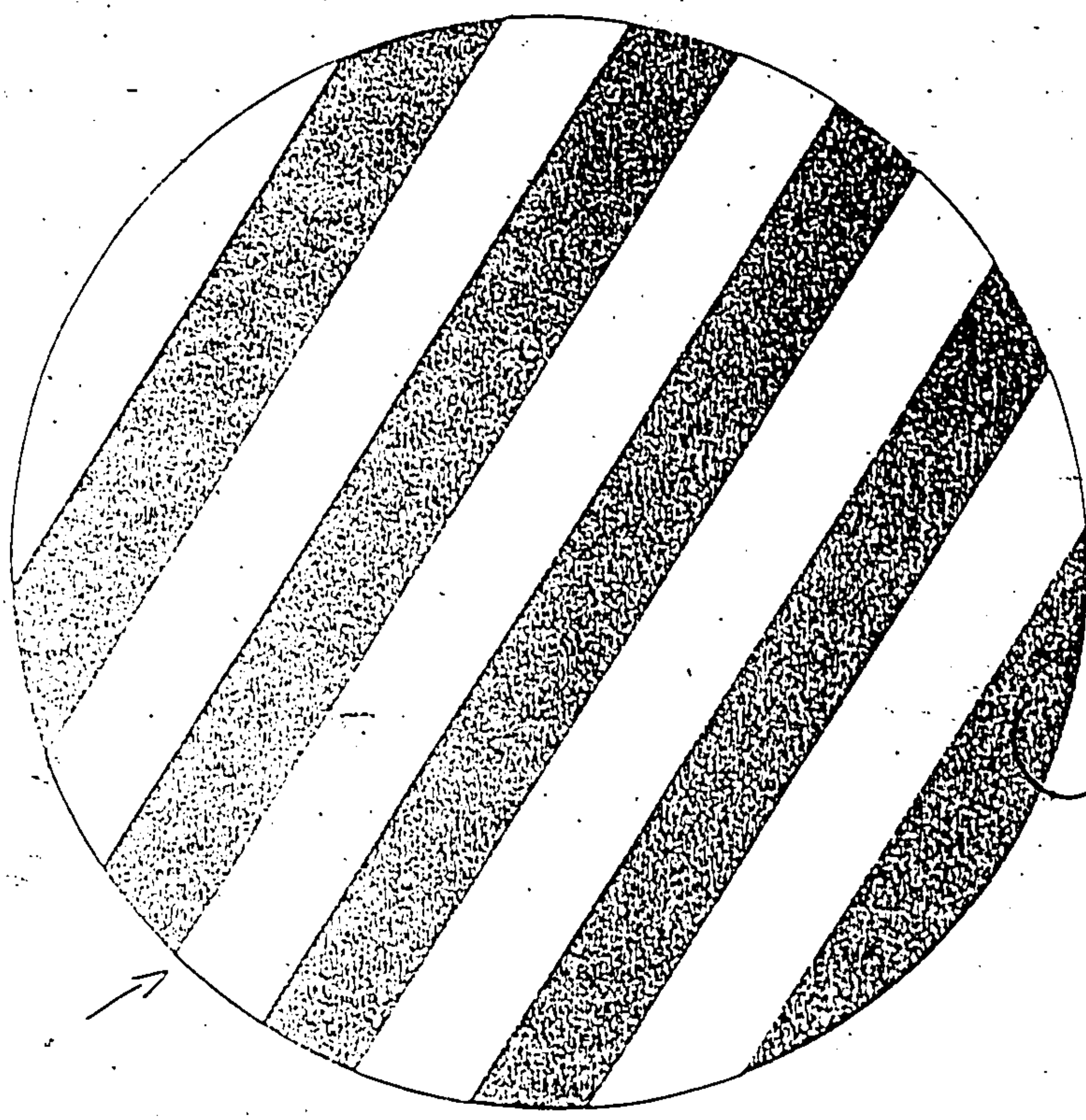


Figure 4. Schematic drawing of circle with stripes oriented obliquely to the right.

Figure 4



DISCUSSION

Infants in all groups looked longer at the stripes in the novel orientation than at those in the habituated orientation. Furthermore, there was no evidence that a mirror-image oblique discrimination was more difficult than a vertical - horizontal one, since no differences were found among the four habituation groups on any measure.

Two explanations may be put forward to account for why infants appeared to be able to discriminate oblique stripes from each other as easily as vertical and horizontal ones. First, it is possible that the infants in this study were able to make the discriminations on some basis other than orientation. Specifically, let us consider the nature of the stimuli used in the present study. At a stripe width of 1.46 cm., a black stripe ends on one side of the circle; a white stripe on the other. Consider what would happen if the infant looked at only one region of the circle during testing, e.g, the left hand region. When an infant was shown left oblique stripes during habituation, he would see mostly black area (refer to Figure 3). However, when he was shown right oblique stripes in the post-test, he would see black/white transitions (refer to Figure 4). It is possible then, that an infant could discriminate these stripes on the basis of differences in contour, brightness or patterning and not orientation per se. We know, however, that when young infants are shown a stimulus, they tend not to scan only one region of the stimulus but rather scan several different areas (Kessen, Salapatek & Haith, 1972). Furthermore, in a recent study, 5-6 week old infants, after being habituated to obliquely oriented stripes, looked longer at stripes oriented along the opposite diagonal than at the habituated oblique stripes. They did not however, look longer at the negative of the 'habituated stripes' (ones in which the ordering of the black and white stripes was reversed) than at the habituated oblique stripes (Maurer & Martello, 1978). These results suggest these infants were processing orientation and not merely regional differences between the stimuli. It is unlikely, then, that the infants in the present study continually looked at only one region of the circle (either during a trial or across trials) and consequently that they were discriminating the different orientations of the stripes on the basis of differences in contour, brightness or patterning.

Second, it is possible that poor oblique discrimination is difficult to detect in infants as young as six weeks of age. We know that at least for meridional anisotrophy, the number of infants who show the effect seems to be a function of age. For example, more 14-20 week old infants show meridional anisotrophy than do 6-13 week old infants (Gwiadza et al., 1977). Consequently, the magnitude of anisotrophy, although minimal at 6-13 weeks of age, is quite pronounced by 14-20 weeks of age. If one assumes that meridional anisotrophy and poor oblique discrimination have the same developmental courses, then one should expect that <u>both</u> effects will be difficult to detect in infants as young as six weeks. This suggests that there would be differences both in the number of infants showing poor oblique discrimination and in the magnitude of this effect shown by each infant, when one compares older and younger infants.

In order to test this hypothesis, I tested orientation discrimination in 17-18 week old infants, most of whom are known to show at least one manifestation of the oblique effect, namely meridional anisotrophy. I expected that if the failure to find poor oblique discrimination in the present study was due to difficulties in detecting the effect at such a young age, then I might find the phenomenon when I tested older infants.

CHAPTER FOUR

EXPERIMENT 3

In order to test orientation discrimination in 17-18 week old infants, it was first necessary to determine a stripe width (spatial frequency) which would be above the threshold of acuity for vertical, horizontal, left and right oblique stripes.

Three spatial frequencies, 1, 2, and 3 cycles/degree, were chosen on the basis of Leehey et al's (1975) data for 14-22 week old infants. Briefly, Leehey et al. reasoned that if infants' acuity for oblique stripes were less than their acuity for vertical and horizontal ones, then at spatial frequencies at or near the threshold of acuity, infants would see the vertical or horizontal stripes more clearly than the oblique stripes and thus would look longer at the vertical and horizontal stripes than the oblique ones. In their study, they reported that 14-20 week old infants looked longer at vertical and horizontal stripes than at oblique ones at 3 cy/deg. A recent replication of their study however, with more subjects and more trials, showed that a significant looking preference for vertical and horizontal stripes also occured at spatial frequencies lower (1.5 cy/deg) and higher (6 cy/deg) than 3 cy/deg (Gwiazda, Brill, Mohindra & Held, 1978). The broad range of frequencies at which a looking preference for vertical or horizontal compared with oblique stripes was found, suggests either high variability in acuity threshold or that the threshold of acuity for oblique lines is considerably lower than that for vertical and horizontal lines for this age group. In any case, it seemed necessary to test acuity at different frequencies to ensure that the value chosen would be above the threshold of acuity for most infants of this age.

I tested acuity for stripes at three frequencies, 1, 2 and 3 cy/deg. The range of these frequencies was similar to that used in Experiment 1, in that the lowest frequency (1 cy/deg) is three times that of the reported threshold (3 cy/deg). Again, I showed infants pairs of circles, one being a grey circle; the other, a circle with black and white stripes, varied in spatial frequency and orientation. I expected that most infants would look longer at the stripes than at the grey circle if the stripes were seen clearly, ie., if that spatial frequency used was well above threshold.

METHOD

Subjects

The subjects were 10 full-term 17-18 week old infants (5 males; 5 females) with no known birth abnormalities. The mean age was 121.6 days (range: 119-126 days).

Stimuli

The stimuli were two circles with black and white stripes oriented at either 90° or 135°. (Only two orientations were tested in this study since Leehey et al. (1975) report no differences between the time infants look at vertical or horizontal stripes or in the time they look at left and right oblique stripes at any of the spatial frequencies they tested. This finding suggests that the threshold of acuity for vertical and horizontal stripes is the same; similarly the threshold of acuity appears to be the same for left and right oblique stripes). The stripes were .36 cm., .18 cm., or .12 cm. wide (1, 2, 3 cy/deg). Each circle subtended 20° of visual angle and was paired with a circle with stripes of a higher (more than 12 cy/deg) spatial frequency (referred to as a 'grey circle'). Each pair was separated by 23° of visual angle. In all, there were 12 pairs of stimuli, including counterbalancing of the side on which the higher frequency circle occurred (3 frequencies x 2 orientations x 2 sides). For each infant, the 12 pairs were shown in a random order.

Apparatus

The apparatus was similar to that described in Experiment 1. Slides were rear-projected onto a screen positioned 45 cm in front of the infant's eyes. Each of the two observers behind the screen had two cumulative timers and a control button which could open a shutter in front of the lens of the projector.

Procedure

The procedure was similar to that described in Experiment 1. Prior to testing, the experimenter placed the infant in the infant seat, turned off the room lights, turned on white noise and presented a female face on the screen to attract the infant's attention.

On each trial a pair of stimuli was shown for 16 seconds. During a trial, each observer activated one of the timers whenever she judged that the infant was fixating the circle on the left. Similarly, she activated a second timer when she judged that the infant was fixating the circle on the right.

At the end of a trial, a shutter automatically closed, and reopened after 10 seconds. While the shutter was closed the viewing screen was blank, and the projector advanced to the next slide. Subsequently, each observer recorded the times from the last trial, cleared the timers and pressed the control button to open the shutter.

Data Analysis

The data analysis was similar to that described in Experiment 1. For a given acuity pair, the mean length of an infant's fixation on each circle of the pair, across the two counterbalanced trials, was calculated and compared. The fixation times used in the calculations were those recorded by the first observer, since complete records were not obtained by the second observer for two infants, because of equipment failure.

To estimate whether the two observers were reliably recording the same behaviour, Pearson Product Moment correlations were calculated separately for the fixation times recorded for 8 infants (since the second observer's records were incomplete for 2 infants). A correlation was calculated separately for times recorded for looking to the left circle and the right circle. The mean correlation was .97 for the left circle (range: .96-.99) and .97 for the right circle (range: .93-.99).

RESULTS AND DISCUSSION

The data are shown in Table 2. Inspection of the group data show that infants looked longer at the striped circle than at the grey circle for each orientation regardless of the spatial frequency. This

Table 2. Individual infants' fixation on each member of an acuity pair in Experiment 3.

Table 2

Subjects	Spatial Frequency					
	1 cy/deg		2 cy/deg		3 cy/deg	
	stripes (90°)	grey	stripes (90°)	grey	stripes (90°)	grey
1	9.6	1.5	3.2	[illegible]*	5.3	3.2
2	7	2.1	8.3	1.5	5.3	2.9
3	4.8	1.5	9.8	1.2	7.2	.25
4	10.4	1.9	9.7	.25	8	3.6
5	10.3	1.4	9.5	2.8	6.4	4.9
6	10.1	2.6	5.2	7.2*	2.6	9.6
7	7	1.7	11.3	.4	5.8	6.5*
8	12.1	.1	10.2	1.7	10.5	1.7
9	10.6	1	2.8	1	3.1	6.4*
10	4.8	1.2	1.6	7*	2.9	3.3*
$\overline{X}$ =	8.67	1.5	7.16	2.65	5.71	4.2
SD =	2.57	.67	3.59	2.54	2.49	2.7
	stripes (135°)	grey	stripes (135°)	grey	stripes (135°)	grey
1	11.2	1.2	7.2	1	2.6	1.9
2	6.2	3.1	9.3	2.3	7.1	.4
3	5.6	1	2.7	.9	2.8	5.5*
4	10.5	1.7	11.9	.3	4.5	7.7*
5	8.1	1.2	5.3	4.8	8.6	2.7
6	9.1	4.5	10.7	1.5	9.9	2.5
7	8.7	.5	12.4	.4	5.2	4.9
8	10.5	2	9.2	2.4	9.9	1
9	8.8	----	9.8	2.6	5.8	4.7
10	5.6	1.5	6.6	.5	6.9	3
$\overline{X}$ =	8.43	1.67	8.5	1.67	6.3	3.4
SD =	2.05	1.30	3.05	1.4	2.64	2.24

* indicates that the infant looked longer at the grey circle than at the striped circle.

finding suggests that 17-18 week old infants are clearly seeing the stripes as different from grey even at 3 cy/deg. This is consistent with Gwiazda et al.'s (1977) acuity findings for 11-20 week old infants.

Inspection of individual infant's performance across the three spatial frequencies, however, indicates that the lowest number of misses (looking longer at the grey circle than at the stiped circle) occured at 1 cy/deg. 0, 3 and 6 misses at 1, 2, and 3 cy/deg, respectively. Thus, I chose a stripe width of .36 cm. (1 cy/deg) as the above threshold value for the subsequent experiments.

EXPERIMENT 4

In experiment 2, six week old infants appeared to be able to discriminate between mirror-image oblique stripes as easily as they can discriminate vertical and horizontal ones.

One possible explanation of these results is that poor oblique discrimination is difficult to detect in six week old infants. This would not be surprising since meridional anisotrophy is also difficult to detect at 6-13 weeks of age (Gwiadza et al., 1977). Assuming that meridional anisotrophy and poor oblique discrimination have the same developmental course, then, it is possible that at 6 weeks of age only a few infants show poor oblique discrimination.

In order to test this hypothesis it seemed necessary to replicate Experiment 2 with older infants. Specifically, I tested 17-18 week old infants since the literature suggests anisotrophy is more pronounced at this age.

Again, I showed infants stripes in one orientation until their looking declined to a criterion of habituation and then presented stripes oriented perpendicular to the ones habituated. In the present study, infants were habituated to stripes in one of two orientations, either left oblique or vertical.

Since no differences in acuity (Cohen-Leehey et al., 1975; Gwiadza et al., 1977) or initial preference (see Appendix A) have been reported between major-orthogonal orientations (e.g., \ and —) or between oblique orthogonal orientations (e.g., \ or /), it was not necessary to counterbalance orientation by testing four habituation groups.

METHOD

Subjects

The subjects were 20 full-term 17-18 week old infants (10 males; 10 females) with no known birth abnormalities. Their mean age was 121 days (range: 119-125 days). Six other infants were also tested but did not complete the procedure because they fussed, cried or slept. The data of one additional infant was excluded because he did not show more looking to the 8 x 8 checkerboard in the post-test than at the stripes at the end of habituation (see below).

Stimuli

There were five stimuli - an 8 x 8 black and white checkerboard and four circles with black and white stripes oriented at either 0°, 90°, 135° or 45°. The stripes were .36 cm. wide (1 cy/deg), a stripe width shown in Experiment 3 to be above the threshold of acuity for both left oblique and vertical stripes. The 8 x 8 checkerboard differed from the stripes in amount of contour (182.5 cm vs 850.82 cm) and in area (224 sq. cm vs 193.66 sq. cm).

All stimuli were presented singly in the center of the field and subtended 20° of visual angle.

Apparatus

The apparatus was similar to that described in Experiment 2. The baby sat in an infant seat in front of a rear projection screen mounted at the end of a table. The stimuli were rear projected onto the screen by a Kodak Carousel projector situated behind it.

Two observers were located behind the screen. Each observer had a timer to record the length of fixations and a control button to open and close a shutter positioned in front of the lens of the projector.

Procedure

The procedure was similar to that described in Experiment 2 except that there was no pre-test. During a trial, eaoh observer activated a cumulative timer when she judged the infant started fixating the stimulus. When she judged the infant to have looked away from the stimulus, she released the timer, pressed the control button to close the shutter and recorded the time. The shutter opened and closed only after both observers had pressed their buttons. Thus, the infant's looking started the trial, his cessation of looking ended the trial. Note that during the post-test slides were advanced manually by the second observer.

For each baby, agreement between the observers' judgements was calculated by Pearson Product Moment correlations. The mean correlation was .99 (range: .80-.99).

Infants were randomly assigned to one of two habituation groups. One group was habituated to vertical stripes; the other to left oblique stripes.

The infant was shown one orientation of the stripes (A) repeatedly until his looking decreased to criterion. As in Experiment 2, the criterion of habituation was two sets of three consecutive trials during which the infant's mean fixation time was less than half of his mean fixation time on the first three habituation trials.

Subsequent to habituation, the infant was given a post-test with three stimuli: stripes in the orientation to which he was habituated (A); stripes oriented perpendicular to the ones to which he was habituated (B) and an 8 x 8 checkerboard (C). Each stimulus was presented twice in either an ABCCBA or BACCAB order with these two orders counterbalanced within each group. Recovery to the checkerboard, that is longer looking at the checkerboard in the post-test than at the stripes at the end of habituation was used to indicate that the infant had truly habituated. The data of one additional infant were excluded from the data analysis because he did not show recovery to the checkerboard.

Results

The data were analysed in two parts: post-test data and habituation data. All time data were transformed to the scale of natural logs prior to statistical analysis to insure homogeneity of variance between the two groups' data (Wiener, 1971). The raw data are shown in the figures.

Post-test Data

To determine whether the infant looked longer at the novel orientation of the stripes than at the habituated orientation, I first obtained a score for each stimulus: for a given stimulus, the mean of the fixation times recorded by the two observers on each trial was calculated and the means were summed across the two trials for that stimulus.

In both groups, infants looked significantly longer at the novel than at the habituated orientations of the stripes. The post-test data are shown in Figure 5. A 2 (habituation groups) x 2 (habituated - novel orientations of the stripes) ANOVA with repeated measures showed that infants looked significantly longer at the novel orientation of the stripes than at the habituated one. There was a significant difference among the post-test stimuli ($F_{1,18} = 26.96$, $p < .01$). No significant between group effect or stimulus x group interaction was found.

<u>Habituation Data</u>

I compared the two groups on four parameters of habituation. As in Experiment 2, the parameters were 1) the number of trials an infant took to reach the criterion; 2) the criterion of habituation; 3) the level of looking at the end of habituation; 4) total fixation time during habituation.

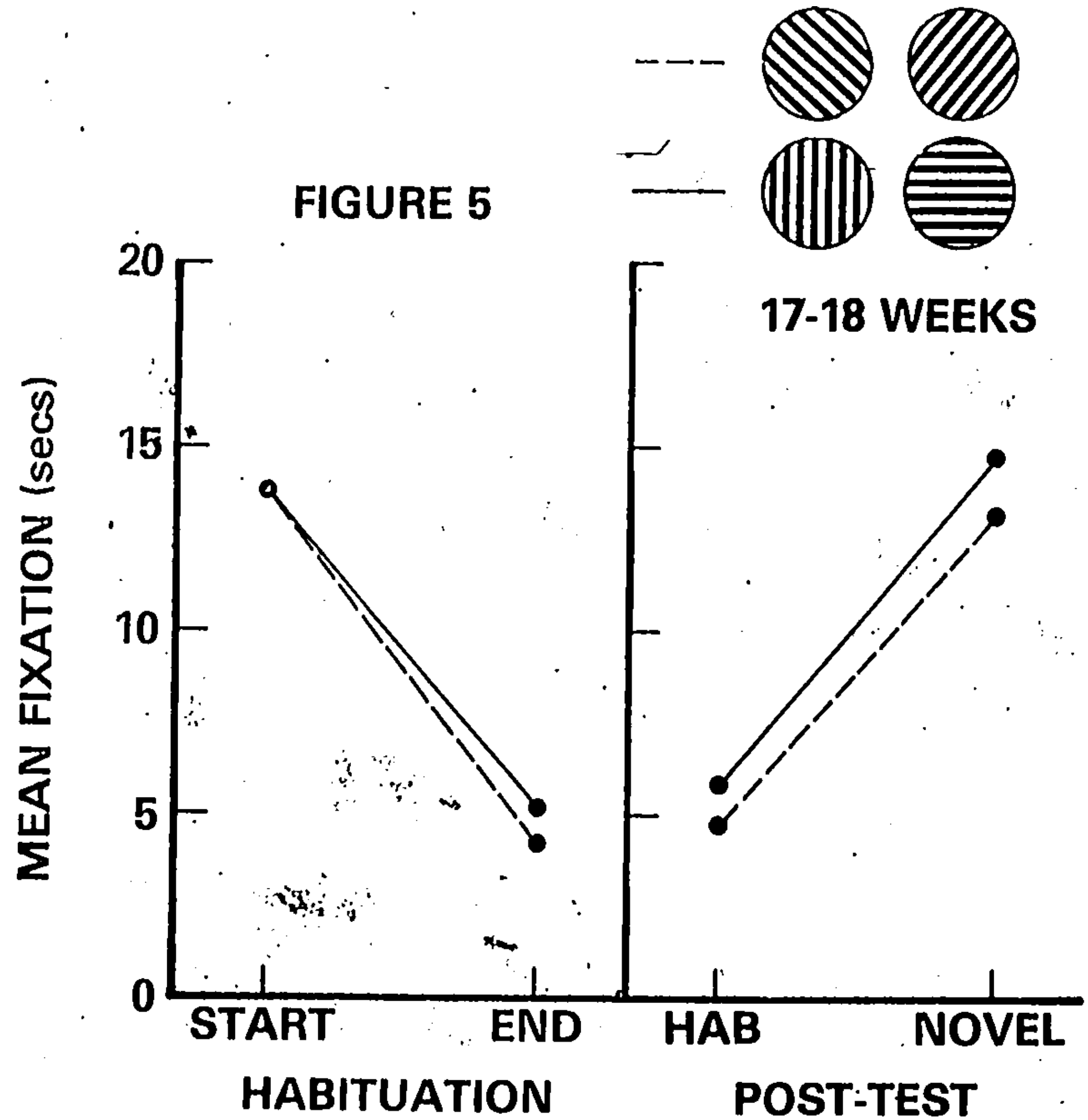
T tests showed that the two habituation groups did not differ significantly on any of these measures.

DISCUSSION

As in Experiment 2, infants in this study looked longer at stripes in the novel orientation than at those in the habituated orientation regardless of whether they were required to discriminate vertical from horizontal stripes or left-oblique from right oblique stripes. The infants appeared to be able to discriminate opposite oblique orientations as easily as major-orthogonal (| vs —) orientations since no difference between the two groups was found.

Figure 5. Mean length of infants' fixation during habituation and post-test in Experiment 4. Vertical habituation group represented by (———); left oblique group by (- - -). For points representing the start of habituation, each infant contributed his mean fixation on the first three habituation trials; for points at the end of habituation, each infant contributed his mean fixation on the second set of criterion trials; for points representing the post-test, each infant contributed the mean of his fixation on two trials.

FIGURE 5


17-18 WEEKS
MEAN FIXATION (secs)
20
15
10
5
0
START
END
HABITUATION
HAB
NOVEL
POST-TEST

It was expected that if meridional anisotrophy and poor oblique discrimination have the same developmental course, then 17-18 week old infants, who are known to show pronounced anisotrophy, should also have difficulty discriminating mirror-image oblique stripes. Failure to find poor oblique discrimination in the present study suggests that these two phenomena may not have the same developmental course.

It remains possible, however, that four month old infants do have difficulty discriminating oblique orientations from each other but that the paradigm used in this study was not sensitive enough to show the difficulty. For example, with an habituation criterion of 50% decrement in visual fixation, infants would be given a generous amount of time to encode the characteristics of the stimulus. Consequently, infants may be able to make an opposite oblique discrimination as easily as a vertical and horizontal one when given ample time to encode the orientations of the stripes but may show difficulty with the oblique discrimination when the length of the habituation period is reduced.

In order to test this hypothesis, I tested orientation discrimination in subseqeunt experiments, using variants of the habituation paradigm. I expected that if infants' ability to discriminate oblique orientations of the stripes was due to certain features of the procedure used in the present study, then I might not be able to replicate these findings when I modified the procedure.

CHAPTER FIVE

EXPERIMENT 5

In the previous experiment, 17-18 week old infants appeared to be able to discriminate between opposite oblique stripes as easily as between vertical and horizontal ones. These data suggest that the 'oblique effect' may not be present in infants of this age.

It still remains possible, however, that four month old infants have difficulty discriminating opposite oblique stripes but that the paradigm used in the previous experiment was not sensitive enough to show this difficulty. In a recent study, Bornstein, Gross and Wolf, (1978) reported that 15 week old infants do have difficulty discriminating opposite oblique lines. Using a 'fixed trial' habituation procedure, Bornstein et al. showed infants a left oblique line for ten trials; each trial lasted ten seconds. This constituted the habituation phase. During the post-test, infants were shown three stimuli: a line oriented obliquely to the left (ie., \), a line oriented obliquely to the right (ie., /) and a line oriented vertically. In the post-test, infants looked equally long at the left and right oblique lines but looked longer at the vertical line than at the left oblique line they had seen during habituation. These data suggest that the infants' were able to discriminate between vertical and left oblique lines but not between opposite oblique lines - hence the 'oblique effect'.

This fixed trial habituation procedure, used by Bornstein et al., differs from the infant-control procedure in a number of ways. First, the length of a trial is kept constant, that is each trial in the habituation and post-test phases is of the same specified length, e.g., 10 seconds. This is quite different from the 'infant-control' version, in which the length of the trial varies not only from trial to trial but also from infant to infant.

Second, in the 'fixed trial' version, not only is the trial fixed but also the number of trials given during the habituation phase is predetermined, e.g., 10. Habituation, then, is not determined by a behavioural criterion as in the infant-control version, (e.g., 50% decrement in fixation) but rather, it is expected that the number of habituation trials presented to the infant is sufficient for habituation to occur.

Given the inherent differences between the 'fixed trial' and 'infant control' versions of the habituation procedure, it is possible that the failure to find poor oblique discrimination in the previous studies may be due to the procedure used. It seemed necessary then to replicate Bornstein et al.'s study with stripes. I showed 17-18 week old infants stripes in the left oblique orientation for ten trials; each trial lasted 10 seconds. Following this habituation phase, I showed infants three stimuli in the post-test: left oblique stripes; right oblique stripes and vertical stripes.

METHOD

Subjects

The subjects were 20 full-term 17-18 week old infants (10 females; 10 males) with no known birth abnormalities. Their mean age was 121 days (range: 119-125 days).

Stimuli

The stimuli were three circles with black and white stripes .36 cm. wide (1 cy/deg), oriented either at 90°, 45°, or 135°. The circles were presented one at a time in the center of the field and subtended 20° of visual arc.

Apparatus

The apparatus was similar to that described in Experiment 4. Slides were rear-projected onto a screen positioned 45 cm in front of the infant's eyes. Each of the two observers behind the screen had a cumulative timer to record the infant's fixations. In addition, there was a shutter in front of the lens of the projector which opened and closed automatically.

Procedure

The experimenter placed the infant in an infant seat and positioned the seat so that the infant's eyes were 45 cm in front of the screen. Prior to testing, the experimenter turned off the room lights, turned on white noise and presented a female face on the screen to attract the infant's attention.

The technique used was the fixed trial habituation procedure described by Bornstein et al. (1978). Infants were shown stripes oriented obliquely to the left (A) for ten successive trials. This defined the habituation phase. Subseqeuntly, each of the following stimuli were presented three times: stripes oriented obliquely to the left (A); stripes oriented obliquely to the right (B); and stripes oriented vertically (C). Each infant saw three randomly selected sets of the six possible combinations of the three stimuli: e.g., ABC, BAC, BCA.

Each trial in the habituation and post-test phases lasted 10 seconds. During a trial each observer activated her cumulative timer whenever she judged that the infant started fixating the circle. At the end of the trial, a shutter automatically closed and the projector advanced to the next slide. Each observer wrote down the time she had recorded on the last trial and cleared the timer. After 7 seconds, the shutter opened and the next trial began.

I calculated agreement between the two observers' judgements by Pearson Product Moment correlation for the 12 infants who were tested by both observers. The mean correlation was .94 (range: .80-.99).

RESULTS

The data were analysed in two parts: habituation data; post-test data. All time data were transformed to the scale of natural logs prior to statistical analysis. The fixation times used in the data analysis were those recorded by the first observer, since the second observer only recorded fixations for 12 of the 20 infants tested.

Table 3. Individual infant's fixation times at the beginning and end of habituation in Experiment 5.

Table 3

Habituation Trials

Subjects	1 + 2	9 + 10
1	13.7	13.1
2	9.6	10.7
3	13.5	11.8
4	17.3	9
5	16.3	11.9
6	11.6	12.6
7	10.4	15.6
8	17.1	16.8
9	14.6	9.1
10	15.8	8.7
11	16.1	17.5
12	12.1	14.8
13	12.5	13.7
14	16.3	8.1
15	15.3	9.4
16	7	3.6
17	16	14.4
18	14.2	14.3
19	13.3	2.9
20	9.4	5.6
X =	13.6	11.48
SD =	2.85	4.3

Table 4. Individual infant's fixation times on post-test stimuli in Experiment 5.

Table 4

Subjects	Stimulus		
	habituated orientation	novel orientations	
	Left Oblique (sec)	Vertical	Right Oblique
1	21.5	19.1	20.5
2	20.8	16.4	15.4
3	24.7	21.1	17
4	23.1	22.5	21.6
5	24.5	24.4	24.9
6	16.8	14.7	6.5
7	18.7	14.5	16.1
8	21.8	14.7	14.2
9	15.9	12.2	13.1
10	19.9	20.7	22.7
11	14.4	12.7	18.1
12	10.6	10.2	17.9
13	14.3	21	18.2
14	10.1	10.7	11.3
15	12.2	21	17.7
16	22.2	23.5	16.3
17	21.8	22.9	19
18	14.1	15.2	9.9
19	12.4	12.7	2.9
20	18.8	23.4	23.1
	$\bar{X}$ = 17.93	18.63	16.32
	SD = 4.67	7.21	5.54
mean fixation per trial	5.98	6.21	5.4

Habituation Data:

To determine whether infants' looking decreased during the habituation phase, I compared the amount of looking at the stripes at the beginning and end of the habituation trials. Specifically, I summed the looking times for habituation trials 1 and 2 and compared this fixation time with the sum for trials 9 and 10. Individual infants' looking times for trials 1 and 2 and for trials 9 and 10 are reported in Table 3. On the average looking decreased by only 2.12 seconds (11%) during the habituation phase. A one way Anova with repeated measures showed that infants' looking did not decrease significantly over the habituation period.

Post-test Data

To determine whether infants looked longer at the novel than at the habituated orientations of the stripes, I first obtained a score for each stimulus. The fixation times on each post-test trial were summed across the three trials for that stimulus.

Individual infants' fixation times on each of the three stimuli are shown in Table 4. Inspection of the table shows that, on the average infants did not look longer at either novel orientation of the stripes, ie., vertical or right oblique stripes, than at the habituated orientation, ie., left oblique stripes.

DISCUSSION

Infants in this study did not look longer at the stripes in either novel orientation, vertical or right oblique, than at those in the habituated orientation. From these data, there is no evidence that infants of this age are able to discriminate between left oblique and vertical stripes or between opposite oblique stripes. This is somewhat puzzling since we know that even 15 week old infants can discriminate vertical from left oblique lines (Bornstein et al., 1978).

There are two possible explanations for the failure to find more looking at either novel orientation in the present study. First, it is possible, that infants were not given enough time to encode the stimulus and consequently did not habituate. This is likely since, in this study, infants' looking did not decrease significantly between the first two and last two habituation trials.

As has been previously mentioned, one of the disadvantages of the fixed trial procedure is that it is not tailored to the individual infant. It is expected that the number of habituation trials given the infant is adequate to allow him to habituate to the stimulus. Typically, however, infants differ with respect to the amount of time they need to habituate. For example, in Experiment 4, infants were shown the habituated orientation of the stripes until their looking decreased by 50%. This behavioural criterion appeared to be effective since all but three infants looked longer at an 8 x 8 checkerboard than at the stripes at the end of habituation - indicating that they had truly habituated. With this criterion, the range of total fixation times during habituation ranged from 29.5 seconds to 490.5 seconds. If I had used a fixed trial procedure, with ten 10 second habituation trials, then less than half of the infants in Experiment 4 would have reached a 50% decrement in looking during the time allowed. Consequently many might not have habituated. Failure to find significant decrement in infants' fixation during the habituation phase in the present study then may indicate that many of these infants had not habituated in the time allowed. It is not surprising, then that more looking was not found to the novel orientations of the stripes in the post-test.

Second, it is possible that the length of the trial during the post-test was too short for the infants to show more looking at the novel orientations. For example, the mean length of fixation during a trial in the post-test was 5.98 seconds for the habituated stripes; 6.21 seconds for the novel vertical stripes and 5.4 seconds for the novel right oblique stripes. In a fixed trial procedure, however, when the stimulus is shown for only 10 seconds, it may typically take up to 5 seconds for the infant to start fixating it. The recorded length of fixation, then, will be limited to the remaining 5 seconds of the trial. Thus infants in the present study might have looked longer at the novel orientations of the stripes if the trial had not ended after 10 seconds.

An estimate of infants' length of fixation on vertical, right oblique and left oblique stripes, when the trials are not a predetermined length can be obtained from a pilot study of preferences (See Appendix A). On the average, infants in the pilot study looked about 11.71 seconds at the vertical stripes; 19.5 seconds at the right oblique stripes and 9.04 seconds at the left oblique stripes. If one compares infants' mean length of looking during a post-test trial in the present experiment with that found during a trial in the pilot study, one would not expect to find more looking to the vertical or right oblique stripes in the post-test. Thus, the failure to find recovery to the novel orientations of the stripes in the present study may reflect a ceiling effect due to the specified trial length.

The question remains, however, as to why infants in Bornstein et al.'s study habituated during the time allowed and showed an increase in looking to at least one of the novel stimuli, even though they were tested with a fixed trial procedure. It should be remembered that the stimulus used in Bornstein et al.'s study was a single line. We know that both the length of an infant's fixation and the number of trials needed for habituation to occur is a function of the amount of contour in the stimulus. For example, Brennan, Ames & Moore (1966) report that 14 week old infants look longer at a 24 x 24 checkerboard compared to a 2 x 2 and 8 x 8 one, while Karmel (1969) reports that 20 week old infants also look longer at patterns with greater amounts of contour. Furthermore, at least in younger infants, Hunter & Ames (1975) report an increase in the number of trials required to reach a criterion of habituation when the number of checks and consequently the amount of contour in the checkerboard is increased. These data suggest that the length of time required to habituate to stripes, which have more contour, would be greater than that required for a single line, which has less contour. It is not surprising, then, that ten 10 second habituation trials were adequate to allow habituation to a single line but not to stripes.

It still remains puzzling, however, that the infants in Bornstein et al.'s study showed recovery to the vertical line and not to the opposite oblique line. Infants might have discriminated the lines on some basis other than orientation[17]. Alternatively it is possible that infants do have difficulties discriminating opposite oblique stripes and that this difficulty is only found when at least three alternatives are presented in the post-test.

In any case, the fixed trial habituation procedure does not appear to be appropriate to test orientation discrimination in 17-18 week old infants when stripes are used as stimuli.

17. An indepth consideration of this possibility will be given with in Chapter 7.

CHAPTER SIX

EXPERIMENT 6

A persistent concern in the study of visual development is whether the method used is a sensitive measure of a particular ability. Whenever we conclude that the visual ability of the infant is different from that of the young child, we are left with the doubt that we did not use an accurate or sensitive enough procedure to test it.

The present series of studies suggest infants can discriminate left from right oblique stripes as easily as vertical from horizontal ones. One would expect the discrimination of mirror-image oblique stripes to be difficult both because they are oriented obliquely and because they are mirror-images. It is possible that young infants, unlike children, do not have difficulty discriminating obliquely oriented stimuli. However, it is also possible that young infants have difficulty discriminating mirror-image oblique stripes, but that the procedure used in these studies is not sensitive enough to show this difficulty. To overcome these problems in interpretation, it seemed necessary to modify the habituation paradigm so that it would be more similar to a recognition task on which young children show mirror-image confusion.

In general, three types of recognition tasks have been used with older children to test discrimination of mirror-image oblique lines: simultaneous discrimination; two alternative forced choice; and successive same/different discrimination (here on refered to as S/D task). Not all these procedures, however, allow unambiguous interpretation of the results. For example, the child's apparent inability to discriminate mirror-image oblique lines in either a simultaneous discrimination or two alternative forced choice task may be caused by procedural effects, eg., stimulus alignment, lack of feedback, etc. (refer to Chapter two). Thus, modelling the habituation procedure after either one of these methods would be inappropriate since clear interpretations of the findings is not possible even with older children.

Extensive review of the literature suggests that the S/D task provides the most easily interpreted measure of mirror-image confusion in young children. In a S/D task, there are no effects of stimulus alignment since the stimuli are presented singly. Furthermore, a child's performance on mirror-image oblique discrimination does not appear to be affected by procedural variants, such as: 1) being told orientation is the dimension relevant to solving the task; 2) being pre-trained on a matching-to-sample task; 3) being required to verbally describe attributes of the stimulus and tested for verbal recall (Stein & Mandler, 1974; Rudel & Teuber, 1963). Thus, with this task, the child's difficulty discriminating mirror-image oblique lines is not limited to particular variants of the procedure as is the case with the simultaneous discrimination and two alternative forced choice tasks.

When trying to model an infant procedure after one used with older children, it is often difficult to determine which aspects of the task are the critical ones to mimic. In the S/D task, single stimuli are presented successively. Children are first given a training phase, during which they learn the characteristics of a standard. Following this training phase, they are given a recognition test which includes at least three stimuli; the standard (eg., \); a mirror-image rotation of the standard (eg., /) and a non-mirror-image rotation of the standard (eg., |).

Mandler and Stein (1974, 1977) suggest that the critical components of the S/D task are 1) successive presentation of the stimuli and 2) the number of alternatives provided in the recognition test. In pilot studies, they report that five year old children show more difficulty discriminating mirror-image oblique lines with a S/D task, in which each alternative in the test phase is presented successively, than in a forced choice task, in which the same number of alternatives are presented simultaneously. Furthermore, performance on either type of recognition test appears to deteriorate as a function of the number of alternatives provided (Mandler & Stein, 1977; Over & Over, 1967).

Although, intuitively, it would seem that the nature of the learning phase would be critical, it does not appear to be. Children's performance on mirror-image discrimination is the same regardless of whether they are shown the standard for only 15 seconds (Stein & Mandler, 1974) or repeatedly until they reach a behavioural criterion of learning (Rudel & Teuber, 1963); whether they are given a 20 second delay before the recognition test, during which they count to twenty (Stein & Mandler, 1974) or are given no delay at all. (For a more complete description, refer to Chapter 2). Thus, the only critical requirement of the learning phase appears to be that the child is given the opportunity to learn the characteristics of the standard and encode them.

The infant-control habituation procedure used in the present series of studies appears to have several of the features of the S/D task. As has been previousy mentioned, with the habituation technique, when the same stimulus is repeatedly shown, an infant's attention to it will decline or habituate (Jeffrey & Cohen, 1971). During this time, it is assumed that the infant is forming an internal representation of the characteristics of the stimulus. Following the habituation phase, presentation of a new or novel stimulus may cause an increase in the infant's attention or 'recovery'. Such recovery provides evidence that the infant can recognize the new stimulus as different from the one he has previously seen (Cohen, 1973; Cohen & Gelber, 1975). This procedure then, can be described as a recognition task in which the infant is both given the opportunity to learn the characteristic of the stimuli and is presented stimuli successively. In this way, it is quite similar to the S/D task in which children show mirror-image confusion with oblique lines.

It still remains puzzling, however, that infants in the previous studies did not have difficulty discriminating mirror-image oblique stripes, given the similarity between the habituation and S/D procedures. Although the infant-control habituation paradigm appears to be reasonably similar to the S/D task there are two aspects of the procedure which may have contributed to the failure to find poor oblique discrimination in young infants. First, in the previous studies, infants saw only two orientations of the stripes in the post-test. We know that in the S/D task, childrens' performance on mirror-image oblique discrimination is a function of the number of alternatives provided in the recognition test. (Mandler & Stein, 1977; Over & Over, 1967). Thus, it is possible that infants did not confuse mirror-image oblique stripes because of the small number of alternatives provided in the post-test. To eliminate this possibility in the present study, infants saw three stimuli in the post-test: the standard or 'habituated' stimulus (ie., \); a mirror-image rotation of the standard (ie., /) and a non-mirror image rotation of the standard (ie., |).

Second, in previous experiments, the criterion of habituation used was two sets of three consecutive trials, during which the infant's mean fixation time was less than half of his mean fixation time on the first three habituation trials. I have argued that with such a criterion, infants would be allowed a generous amount of time to encode the stimulus. It may be possible that infants are able to discriminate oblique stripes as easily as vertical and horizontal ones only under these circumstances. Thus, in the present study, I allowed infants less time to encode the stimulus. Specifically, I required that ~~for~~ only three consecutive trials, the infant's mean fixation time be less than 75% of that on the first three habituation trials.

Given these procedural modifications, I expected that if infants have difficulty discriminating mirror-image oblique stripes, then in the post-test, they would either 1) look equally long at the novel and habituated oblique stripes but longer at the vertical stripes than at the habituated oblique stripes or 2) look longer at both novel orientations of the stripes than at the habituated oblique stripes but the length of looking at the vertical stripes would be longer than that at the novel oblique stripes.

METHOD

Subjects

The subjects were 18 full-term 17-18 week old infants (9 females; 9 males) with no known birth abnormalities. Their mean age was 122 days (range: 119-126 days). Five other infants were also tested; 2 did not complete the procedure because of crying or fussing; 3 did not complete the procedure because of experimenter error. The data of two additional infants were excluded because they did not show the expected recovery to the checkerboard.

Stimuli

There were four stimuli - an 8 x 8 black and white checkerboard and three circles with black and white stripes oriented at 90°, 45° or 135°. As in previous experiments the stripes were .36 cm. wide (1 cy/deg). The 8 x 8 checkerboard differed from the stripes in amount of contour (182.5 cm vs 850.82 cm) and in area (224 sq. cm vs 193.66 sq. cm).

All stimuli were presented singly in the center of the field and subtended 20° of visual angle.

Apparatus

The apparatus was the same as that described in Experiments 2 and 4.

Procedure

The procedure was similar to that described in Experiment 4.

During a trial, each observer activated a cumulative timer when she judged the infant started fixating the stimulus. When she judged the infant to have looked away from the stimulus, she released the timer, pressed the control button to close the shutter and recorded the time. The shutter opened and closed only after both observers had pressed their buttons. During the post-test, slides were advanced manually by the second observer. The mean correlation between the two observers' judgements for a baby was .98 (range: .95-.99).

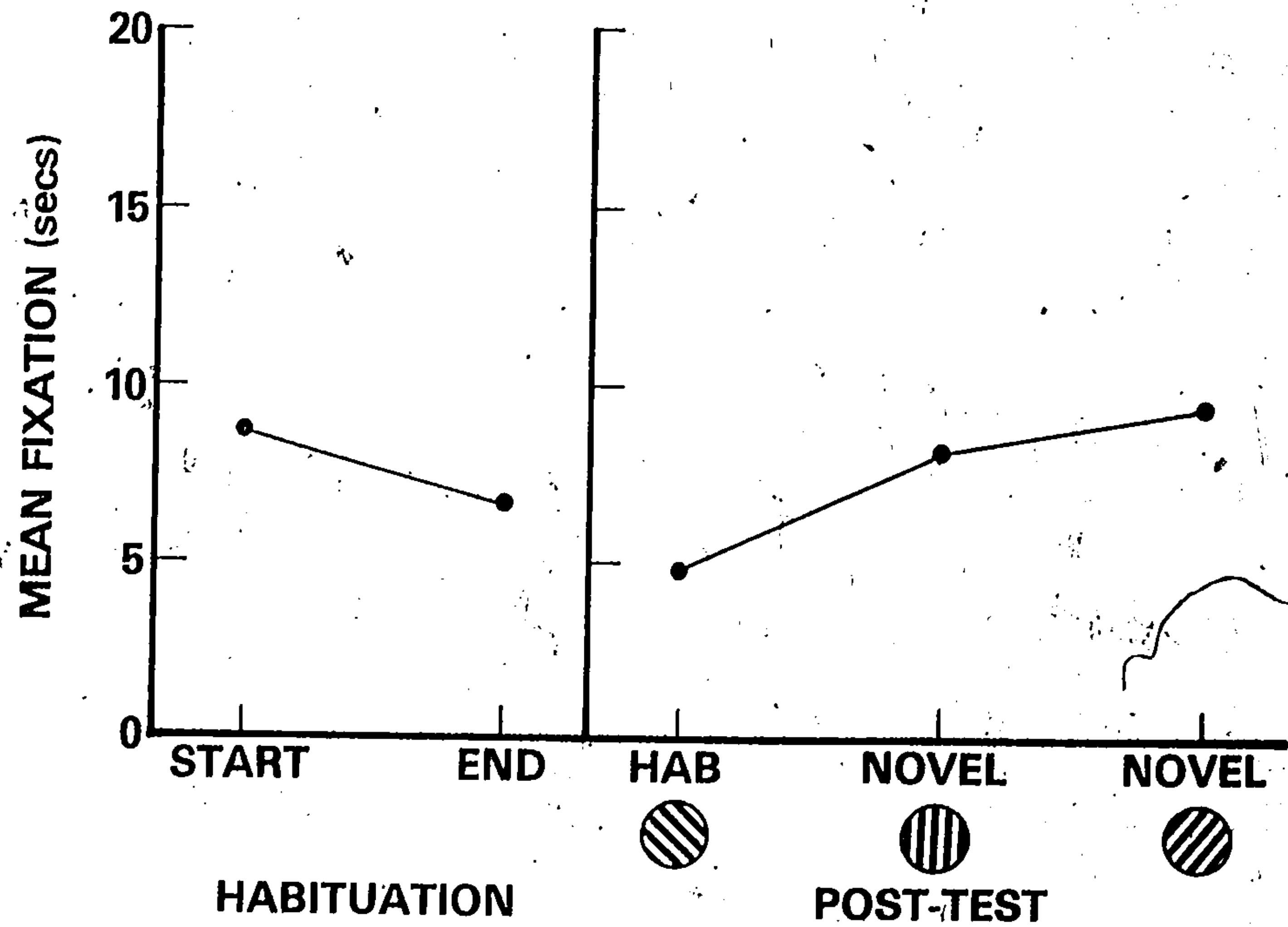
Infants were shown stripes oriented at 135° (A) repeatedly until their looking decreased to criterion. The criterion used was one set of three consecutive trials during which the infant's mean fixation time was less than 75% of his mean fixation time on the first three habituation trials. As in Experiments 2 and 4, the fixation times used throughout habituation to determine the criterion were the larger of the two recorded by the two observers on each trial, since this provides the more conservative estimate of habituation.

Subsequent to habituation, the infant was given a post-test with four stimuli: the same stripes oriented at 135° (A); stripes oriented at 45° (mirror-image rotation) (B); stripes oriented at 90° (C), and an 8 x 8 checkerboard (D).

Each stimulus was presented twice with the two 8 x 8 checkerboard stimuli shown at the end of the post-test. Each infant saw one set of the six possible combinations of the three orientations of the stripes: e.g., ABC or BAC etc. and each infant saw the same set twice, eg., ABCCBADD or BACCABDD, etc. The six orders were counterbalanced within the group.

Figure 6. Mean length of infants' fixation during habituation and post-test in Experiment 6. Each point on the graph represents the mean of infants' fixation on a trial.

FIGURE 6


MEAN FIXATION (secs)
20
15
10
5
0
START
END
HAB
NOVEL
NOVEL
HABITUATION
POST-TEST

As before, more looking at the 8 x 8 checkerboard than at the stripes at the end of habituation was used to indicate that the infant had truly habituated. The data of two additional infants were excluded from the analysis because they did not show recovery to the checkerboard.

RESULTS

To determine whether an infant looked longer at the novel orientations of the stripes than at the habituated one, I first obtained a score for each stimulus in the post-test: for a given stimulus, the mean of the fixation times recorded by the two observers on each trial was calculated and the means were summed across the two trials for that stimulus. Again all time data were transformed to the scale of natural logs prior to statistical analysis but the raw data are shown in the figures.

On the average, infants looked longer at both novel orientations of the stripes than at the habituated one. The post-test data are shown in Figure 6. A one-way ANOVA with repeated measures showed there was a significant difference in the length of infants' fixations to the three orientations of the stripes in the post-test ($F_{2,34} = 5.05$, $p < .025$). Tukey post-hoc analysis showed that infants looked significantly longer at both the novel oblique ($D = .45$, $p < .05$) and vertical ($D = .47$, $p < .05$) orientations of the stripes than at the habituated oblique stripes. As can be seen in Figure 6, there was a slight tendency for infants to look longer at oblique stripes oriented to the right (mirror-image rotation) than at the vertical stripes. A Tukey post-hoc analysis showed that this difference was not significant ($D = .02$, $p < .05$).

DISCUSSION

In the present study, infants looked longer at both novel orientations of the stripes, vertical and right oblique, than at the habituated one. Thus the infants appeared to be able to discriminate left oblique stripes both from right oblique stripes and from vertical stripes.

Difficulty discriminating between mirror-image oblique stripes could have been shown by one of two patterns of results: 1) increased looking to only the vertical stripes; 2) increased looking to both right oblique and vertical stripes, with more looking to the vertical stripes. In the present study, infants looked just as long at both novel orientations of the stripes. If anything, they tended to look longer at the right oblique stripes than at the vertical stripes. The present results, then suggest that 17-18 week old infants can discriminate oblique orientations from each other as easily as they can discriminate left oblique from vertical ones.

Several studies have shown that children as young as five years have difficulty discriminating mirror-image oblique lines when given an S/D task (Rudel & Teuber, 1963; Stein & Mandler, 1974). In contrast, the present findings suggest that 17-18 week old infants have no difficulty discriminating mirror-image oblique stripes. This is a surprising finding since the procedure used in the present study has several features in common with the S/D task: namely, 1) it is a recognition task; 2) stimuli are presented successively, 3) more than two alternatives are provided in the recognition test.

It is possible that the difference between the present results and those found with young children, is due to artefacts in the procedure. For example, it might be argued that with an habituation criterion of 25% decrement in visual fixation, infants are still allowed an excessive amount of time to learn the characteristics of the stimulus. Again, it is possible that infants are able to make an oblique discrimination when given a generous amount of time to encode the orientation of the stripes but may show difficulty when the length of the habituation period is reduced. This appears to be unlikely. As was noted in the introduction, the length of the training phase in an S/D task does not appear to be a critical variable influencing children's discrimination performance. Children who are trained to a behavioural criterion to learn the appropriate response to one member of a pair of discriminanda (Rudel & Teuber, 1963) show the same difficulty discriminating mirror-image stimuli as children who are given only 15 seconds to learn the characteristics of the standard (Stein & Mandler, 1975).

Thus, it is unlikely that 17-18 week old infants' ability to discriminate mirror-image oblique stripes was mainly due to the nature of the paradigm used. The most likely explanation of this finding is that infants of four months do not show the oblique effect in an above threshold discrimination task.

CHAPTER SEVEN

GENERAL SUMMARY AND CONCLUSIONS

Young infants have been reported to show meridional anisotrophy, i.e., reduced acuity for obliquely oriented stripes compared with vertical and horizontal ones. This thesis attempted to determine whether young infants also show more difficulty discriminating between mirror-image oblique stripes than between vertical and horizontal ones, when the stripes are above the threshold of acuity.

In Experiment 2, six week old infants appeared to be able to discriminate opposite oblique stripes as easily as they could vertical from horizontal ones. One possible explanation for these results was that at this age, poor oblique discrimination, like meridional anisotorphy, is difficult to detect. The results of Experiment 4, however, suggests that age was not the reason for the difficulty in detecting poor oblique discrimination in Experiment 2. Seventeen to eighteen old infants, who are known to show pronounced anisotrophy, also did not have difficulty discriminating mirror-image oblique stripes. It remained possible that the failure to find poor oblique discrimination in 17-18 week olds was due to the nature of the paradigm used. The results of Experiment 6, however, suggest that the nature of the paradigm was not the critical factor in Experiment 4. Seventeen-eighteen week old infants were still able to discriminate oblique stripes from each other as easily as they could discriminate left oblique stripes from vertical ones even when they were given less time to encode the stimulus during habituation and were given three alternatives in the post-test. The findings of this thesis, then, suggest that six week old and even four month old infants do not show any evidence that a discrimination between mirror-image oblique stripes is more difficult than one between vertical and horizontal stripes.

It still remains puzzling, however, that infants in Bornstein et al.'s (1978) study showed difficulty discriminating mirror-image oblique lines while the infants tested in the present series showed no difficulty discriminating mirror-image oblique stripes. Two explanations can be put forward to account for the disparity between Bornstein et al.'s results and those from the present experiments.

First, the stimuli used in Bornstein et al.'s study were single lines while those used in the present series of studies were stripes. It is possible that poor oblique discrimination is only found when orientation discrimination is tested with lines. We know, however, that young children show mirror-image oblique confusion regardless of whether they are tested with single lines (Over & Over, 1967; Rudel & Teuber, 1963), or geometric C's (Thompson, 1975). Thus, it seems unlikely that the nature of the stimuli (ie. stripes) used in the present series of studies affected infants' ability to discriminate between mirror-image oblique stimuli.

Second, in Bornstein et al.'s study, the length of a trial during habituation was only 10 seconds. Since this time period is short, it is possible that these infants were encoding some feature of the stimulus other than 'exact' orientation. For example, it is possible that one of the first features the infant encodes is whether or not the stimulus is slanted and only after does he encode exact orientation. Consider what this would mean with respect to the discrimination of vertical and left oblique lines compared with that of mirror-image oblique lines. If infants were discriminating the lines on the basis of 'line slope', then they would show evidence of discrimination between vertical and left oblique lines since one line (eg. \ ) has the property 'slant'; the other (eg. |) 'no slant'. This strategy, however, would not allow the discrimination of mirror-image oblique lines since both lines have the property of 'slant'. Note that this is the pattern of results Bornstein et al. found.

In Bornstein et al.'s study, then, infants may have made the discriminations on the basis of 'line slope' rather than 'exact' orientation, due to their brief exposure to the stimulus during an habituation trial. Thus these investigators might not have obtained the same pattern of results if infants were given sufficient time to encode the orientation of the stimulus.

Before one can be confident that Bornstein et al.'s findings represent the 'oblique effect', the possibility that infants were making the discriminations on the basis of line slope must first be ruled out. This hypothesis could be tested by comparing infants' ability to discriminate horizontal from vertical lines with their ability to discriminate horizontal from left oblique lines under the same procedural constraints employed by Bornstein et al. If infants are only encoding 'line' slope, they should be able to discriminate horizontal from left oblique lines, since one (eg. ╲) has the property of 'slant'; the other (eg. —) no slant. They should not however, be able to discriminate horizontal from vertical lines, since both lines have the property of 'no slant'. Alternatively, if infants are encoding exact orientation of the line then they should be able to make both these discriminations.[18]

Regardless of Bornstein et al.'s findings, the data from the present series of studies suggest that infants even at four months of age do not show the oblique effect in an above threshold discrimination task. These findings are quite surprising given what we know about the development of meridional anisotrophy, supposedly another manifestation of the oblique effect. Although it is generally assumed that meridional anisotrophy and children's difficulty discriminating mirror-oblique lines are both manifestations of the same 'oblique effect' (Appelle, 1972), there is no reason to believe that both these phenomena develop at the same time and that they are generated by the same underlying mechanisms. We know that meridional anisotrophy is shown by infants as young as six weeks of age and that it becomes more pronounced during the first year of life (Leehey et al., 1975; Gwiazda et al., 1977). In contrast, the present findings suggest that

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18. Note that 7-12 week olds and even newborns can discriminate vertical from horizontal stripes (Mackenzie & Day, 1971; Slater & Sykes, 1978). In these studies, however, the lengths of time infants were given to encode the characteristics of the stimulus were different from that in Bornstein et al.'s study. Thus, it is not possible to know whether infants would show evidence of being able to discriminate between vertical and horizontal lines under the same conditions used by Bornstein et al.

difficulty discriminating mirror-image oblique stripes is not shown even by 4 month old infants. The disparity between the development of these two phenomena suggest that they are probably not both manifestations of the 'oblique effect'. It is also likely that meridional anisotrophy and poor oblique discrimination are generated by very different mechanisms.

The question remains, then, as to why older children have difficulty discriminating mirror-image oblique stimuli while young infants do not. Recently, Braine (1978a; 1978b) has proposed a three level model of processing orientation to account for childrens' mirror-image confusion of oblique lines. Briefly, Braine proposes that the first level of processing orientation is very primitive and limited. Specifically, at this level, the young child makes a judgement of orientation which classifies the stimulus as 'upright' or 'non-upright'. At this level, children can only discriminate between 'upright' and 'non-upright' instances of the stimulus. Differentiation of the 'non-upright' category requires higher levels of processing. At the second level, children can identify stimuli as 'upside down' or 'sideways'. Finally, at the third level, children can differentiate the 'sideways' category into 'left-turned' and 'right turned' instances of the stimulus. Furthermore, it is not until this level has developed that children are able to differentiate between diagonals slanted to the left and to the right. These levels of processing orientation, Braine argues, can be "...construed as consequences of developmental periods and as different levels at which orientation is processed at all ages." (Braine, 1978a, p. 27).

There are at least two predictions that follow from Braine's model. First, since the different levels of processing orientation can be found at all ages (that is once they have all developed), then one might expect to find that even adults would have difficulty with a third level discrimination under some circumstances. Wolff (1971) and Sekuler & Houlihan (1968) report that adults, when required to make same/different judgements, have longer reaction times when discriminating between left-turned and right-turned instances of a stimulus. These data, then, support this prediction.

Second, since the third level of processing orientation, that is one in which diagonals slanted to the left and to the right can be differentiated, is the last to develop, then one would expect that not only young children but also young infants should show difficulty discriminating between mirror-image stimuli. Although the data on mirror-image confusion in young children (Over & Over, 1967; Rudel & Teuber, 1963) appear to support this prediction,

the data from the present series of studies does not. The findings of this thesis would indicate that the third level of processing orientation is present in young infants since infants showed no evidence that a discrimination between mirror-image oblique stripes was more difficult than one between vertical and horizontal stripes. The data on orientation discrimination in young children, however, would indicate that the third level of processing orientation has not developed even by 8 years of age, since these children show mirror-image confusion of mirror-image oblique lines (Rudel & Teuber, 1973). The contradiction between these two sets of data suggest that the three level theory of processing orientation as presently formulated by Braine, is not adequate for explaining the mechanism underlying young childrens' mirror-image confusion of oblique lines.

Olson (1970; 1977) has proposed an alternative theory to explain poor oblique discrimination. He suggests that the discrimination of oblique stimuli is problematic because of our mental representation of space, ie. a three dimensional Euclidean space comprised of three major axes: up/down, right/left and front/back. Unlike other orientations of a stimulus, obliquely oriented stimuli do not fall on one of the three major axes and thus require a compound representation in this spatial schema. For example, a left oblique line represents a line coded as up and to the left. Olson suggests that because of this compound representation, obliquely oriented stimuli are time consuming to recognize and their recognition is late in developing.

It follows from Olson's formulation, that one should not expect to find poor oblique discrimination until one represents space according to Euclidean spatial relationships. Young infants, then should not have difficulty discriminating oblique stimuli since they do not represent space according to Euclidean spatial relationships (Piaget & Inhelder, 1956). In contrast, young children who represent space according to Euclidean Spatial relationships, should have difficulty discriminating mirror-image oblique lines. Considered together, the data from the present series of studies and those from studies of mirror-image discrimination in children, tend to support this prediction.

In conclusion, the findings of the present thesis suggest that young infants even at 4 months of age do not have difficulty discriminating mirror-image oblique stripes. Furthermore, they suggest that poor oblique discrimination and meridional anisotrophy are two distinct phenomena which are generated by different underlying mechanisms.

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APPENDIX A

To determine whether 17-18 week old infants would initially look at one orientation of the stripes longer than at another, we tested infants with a modification of Fantz's et al (1962) preferential looking technique.

Eight infants were presented five stimuli successively, an 8 x 8 black and white checkerboard and four circles with black and white stripes .36 cm. wide (1 cy/deg), oriented either at 0°, 90°, 45°, or 135°. Each stimulus was shown twice with order of presentation randomized. The apparatus was the same as that described in Experiment 4.

During a trial, each observer activated a timer when she judged that the infant started to fixate the stimulus. When she judged the infant to have looked away from the stimulus, she released the timer; recorded the time and pressed the button to advance the projector. For each baby, agreement between the observers' judgements was calculated by Pearson Product Moment correlations. The mean correlation was .98 (range: .89-.99). For each infant, I calculated the mean of the fixation times recorded by the two observers on each trial. Then I calculated the mean length of time an infant looked at each stimulus, across the two trials.

The data are shown in Table 5. A one way ANOVA with repeated measures showed there were no significant differences in the time infants looked at any of the five stimuli. Thus 17-18 week old infants showed no preference in their looking at either vertical, horizontal, left oblique, right oblique stripes or an 8 x 8 checkerboard.

Table 5. Mean length of infants' fixation to vertical stripes, horizontal stripes, left oblique stripes, right oblique stripes and 8 x 8 checkerboard.

Table 5

	vertical stripes	horizontal stripes	left oblique stripes	right oblique stripes	8 x 8 checkerboard
mean fixation per trial (sec)	11.71	11.77	9.04	19.5	12.39
SD	5.22	6.58	4.8	10.24	9.16