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CEREBRAL ASYMMETRY AND THE INFANT'S PERCEPTION OF EMOTION

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CEREBRAL ASYMMETRY AND
THE INFANT'S PERCEPTION OF EMOTION

by

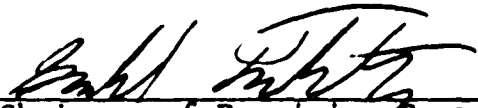
Barbara Stimmel

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

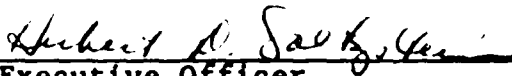
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ABSTRACT

CEREBRAL ASYMMETRY AND THE INFANT'S PERCEPTION OF EMOTION

by
Barbara Stimmel

Advisor: Professor Gerald Turkewitz

Two studies were done to assess cerebral asymmetry for processing of emotion in infants. Both experiments used split-screen tachistoscopic presentation of stimuli to six- to seven-month old infants with heart rate change as the dependent variable. In Experiment 1 subjects were presented with four habituating trials, each the face of a different adult with the same expression. The fifth trial was the presentation of yet another adult with a different expression from that in the habituating trials. Experiment 1 yielded no main effects. There was a significant interaction ($p < .02$) between visual field and order. It appears there was a priming effect such that increased deceleration occurred during stimulation of the visual field contralateral to that stimulated first. This occurred regardless of which visual field was stimulated first.

In Experiment 2, the habituation phase included six trials of identical stimuli (same face/same expression) with a seventh trial that was either same face/different expression, different face/same expression, or a change in both face and expression. Marginal significance ($p < .06$) for dishabituation was found on a repeated measures ANOVA. There was also a significant second order interaction ($p < .01$) between visual field, trial, and order of visual field stimulation. This interaction resembled that in Experiment 1 in that responding in the opposite visual field to that stimulated first produced greater deceleration than in the ipsilateral visual field.

While there was no explicit evidence of hemispheric asymmetry for the perception of affect in infants, the replication of interactions suggested priming effects of order of hemispheric engagement.

The dishabituation observed in the second experiment is the first reported example of the successful use of the split-screen method combined with the habituation paradigm with infants in order to measure asymmetry in the visual mode.

Theories of development of asymmetry are presented. The data suggested that hemispheric specialization for processing of affect is not clearly functional in infants but may be facilitated by specific environmental constraints.

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INTRODUCTION

Is the capacity of the human infant to perceive emotion from facial expressions hemispherically localized? This question is embedded in the more general question of hemispheric localization for facial recognition. Research will be reported which was done in an attempt to further our understanding of this aspect of the ontogenetic relationship between brain and behavior.

As preparation, a review of several bodies of literature which pertain to the questions raised will be presented. They are 1) face perception, 2) perception of emotion, 3) the interaction of face and emotion perception, 4) hemispheric asymmetry in general and 5) hemispheric asymmetry with regard to the perception of faces and emotion. Throughout, there will be references to infant, child, and adult subject populations.

A. Face Perception

1. In Infancy

The ability of humans to make hundreds of faces sufficiently familiar over short periods of time, to allow for recognition at a later date, is of interest. That encoding of new faces rarely interferes with those already committed to memory indicates an enormous yet prosaic

memorial capacity. The basis as well as limitations of this function have not been adequately described. Although determining exactly how one recognizes a face is an unsolved problem, it is general knowledge that human beings are remarkably competent at this task (Harmon, 1973).

The human face is a salient stimulus. There is evidence to show that infants minutes old will preferentially track a moving schematic face as opposed to three other similar stimuli (Goren, Sarty, & Wu, 1975). Neonates are also presumed able to discriminate facial expression (happy, sad, and surprised) because they have been shown to differentially habituate to live models exhibiting these expressions (Field, Woodson, Greenberg, & Cohen, 1982). The initial attention paid to faces, however, appears to be of a piecemeal nature (Caron, Caron, Caldwell, & Weiss, 1973; Diamond & Carey, 1977; Hainline, 1978); with the hairline and eyes being a stronger cue than the mouth-nose arrangement, for example. Apparently the configuration "whole face" does not control preferential looking until approximately 15 to 16 weeks (Haaf, 1977; Haaf & Bell, 1964; McCall & Kagan, 1967). These studies suggest that before this age attention and interest are determined by other properties, e.g., contrast, brightness, and general visual complexity. Also,

beginning at this age (15 to 16 weeks) upright faces begin being preferred to inverted ones (Fagan, 1972; McGurk, 1970; Watson, 1966).

Although the predominant area of attention for a young infant is the hairline-eye region, there is evidence that infants encode faces in a rudimentary abstract manner similar to the adult. For example, Fagan (1976) has shown that infants (5-6 months) who have habituated to either a profile or three-quarter view of a person's face will then prefer viewing a different person than the original when presented with the two front views of the model. In other words, the infant is able to recognize full-face presentation from profile views of the same face.

Fagan (1973) used the preferential looking technique to show recognition memory in five-month olds. Subjects remembered a photographed face for up to fourteen days after presentation of that face. Maurer and Salapatek (1976) showed that infants as young as four weeks of age will look at their mothers' faces for a significantly shorter period of time than at the unfamiliar faces of other females and males. Cornell (1974) also demonstrated that infants from 19 to 23 weeks were able to discriminate among photographs of faces. As Carey (1981) put it, "Faces are distinguished from other stimuli in the first few months of life and at the same time the mother's face

is distinguished from other faces." Therefore, it seems fair to say that by the age of six months infants are capable of distinguishing faces to which they have been exposed in different poses and over significant periods of time while also maintaining their representations.

2. In Childhood

It is important to note that children under eight years of age are essentially not as capable of encoding unfamiliar faces as are children over the age of ten. There is steady improvement in this behavior from the ages of two to ten, and by ten "they approach, if they do not actually achieve, the normal adult level" (Carey, 1981). The changes between the ages of five and ten occur in the area of representation and recognition of unfamiliar faces rather than familiar faces (Carey & Diamond, 1977; Diamond and Carey, 1977; Goldstein and Chance, 1964; Kagan and Klein, 1973).

There is little dispute that facial recognition is part of the human repertoire and that it begins at an early age. Given that the capacity to encode, recognize and recall faces on the part of human beings is an extraordinarily adaptive one, and one that begins developing early in life, it seems reasonable to consider and study the ability of humans to perceive emotion in the face.

Human judgment of emotion is also extremely adaptive in terms of assessing and understanding the situation in which a human being finds himself as well as being able to predict consequences and behave appropriately, i.e., adaptively, in any given situation. An argument could be made that the ability to perceive emotion is a basic and necessary biological adaptive response of the newborn.

B. Perceiving Emotion

1. General Findings

As Ekman and Oster (1979) point out, systematic research in the area of facial expressions, affect or emotion has been "episodic." Although historically several well-known psychologists, for example Allport, Boring, Guilford, and Titchener, have paid some attention to this area of study, their efforts were sporadic and the resulting knowledge minimal. It is interesting to note that it was Charles Darwin (1872) with the publication of "The Expression of the Emotions in Man and Animals," who laid the groundwork for studies to follow. He attempted to systematize and categorize emotions expressed in the faces of subhuman primates, some other wild animals (e.g., the fox and wolf), as well as domesticated animals such as dogs and cats. It was his contention that these expressions are invariant within species and have primarily a communicative function. He did major cross-

cultural studies as well as developmental studies and photographic recognition studies in an attempt to explore the possibility that human emotional expression is universal. He was also interested in understanding its communicative function among humans.

Having laid this foundation as well as having a major impact on researchers to follow (see, e.g., Andrew's 1965 review), it is interesting that more than 100 years after the publication of Darwin's book there is still poor understanding of the expression and perception of human emotion. Based on Tomkins and McCarter (1964), who showed that high agreement can be obtained in judging emotion when facial expressions are selected to show what Tomkins believes to be innate or intrinsic facial affects, Ekman (1972), Ekman and Friesen (1971), and Izard (1971) have done major cross-cultural studies of facial expression with results that indicate universality of facial expression. Although the initial cross-cultural studies were done with primarily literate cultures with still photographs, studies were subsequently done with pre-literate cultures in Papua, New Guinea in order to refute the argument that those tested had all been exposed to the same mass media and therefore had learned the same typical facial expressions.

Gitter, Mostofsky, and Quincy (1971) found that sex and race differences in children did not affect the ability to accurately perceive emotional expression in their own and different racial group models. Another study (Winkelmayer, Exline, Gottheil, & Paredes, 1978) responded to the criticism that experiments such as these utilized still photographs of expressions which were posed by models, the argument being that judgments of facial expression were perhaps limited to stereotyped posed expressions. Winkelmayer's study used motion picture samples of normals and schizophrenics to determine if adult subjects would score as well when judging emotions from cultures different than their own as well as different states of psychological adjustment in a spontaneous rather than posed context. They found no significant differences in judgment of emotion between American, British, and Mexican observers under these conditions.

Ekman (1972) did a similar study in which Japanese and American observers were asked to judge whether the facial expressions of Japanese and American individuals were evoked by watching a stressful or neutral film. Adult subjects were equally accurate whether they were judging members of their own or the other culture. Another significant finding of this study is that the

persons judged correctly by Americans were the same as those judged correctly by Japanese.

Triandis and Lambert (1958) using Schlosberg's (1954) Lightfoot photographs¹ showed rating concordance of emotion between Greek and American subjects. Saha (1973) using the same photographs reported similar findings with Asian Indians. Izard (1971) also used a free naming technique and found similarity among four cultures. Of all the studies reported, however, there is only evidence for the universality of the expressions of happiness, anger, disgust, sadness, and combined fear or surprise (Ekman, Sorenson, & Friesen, 1969; Izard, 1971; Saha, 1973).

It has been shown that spontaneous production as well as the judgment of some spontaneous facial expression is relatively invariant across cultures. Ekman and Friesen (1971) showed that when members of a preliterate group (New Guinea) were asked to pose specific emotions, their facial movements were the same as members of literate cultures who were asked to perform the same task. It is well known that adults produce facial expressions which

¹ A series of photographs showing the same female face with different facial expressions which display the scope of variability of Schlosberg's theoretical range of facial expression: pleasantness/unpleasantness, attention/rejection, and sleep/tension.

are very similar to those exhibited in early infancy, for example, disgust, startle, smiles.

There is further corroboration of the fact that these expressions are "prewired" by the studies of congenitally blind infants. These studies (see Charlesworth & Kreutzer, 1973) give evidence that imitation of other human beings is unnecessary for the infant to produce facial expressions such as smiles and frowns.

2. Developmental View

Although it is not clear whether responding indicates an accurate perception of emotion or just a response to stimulus differences among the stimuli, several investigations report differential responding to emotional stimuli in infants. From three to four months of age infants respond differentially to various facial expressions. The studies of LaBarbera and Izard (1976) and Young-Browne, Rosenfeld and Horowitz (1977) show that there is differential fixation to slide presentation of happy versus neutral or angry faces and surprise versus happy faces in three- to four-month olds. Nelson, Morse, and Leavitt (1979) present similar findings with seven-month olds discriminating happy faces from those showing fear.

As with the development of the capacity to encode unfamiliar faces and recall them at another time, the

development of the perception of facial affect also changes over time. As the studies described above indicate, babies as young as four months show preference for emotion wherein they look longer and more frequently at faces that express joy than anger or neutral expressions.

In studies by Ekman and Friesen (1971), Gates (1923), Izard (1971), and Kellog and Eagleson (1931), it has been shown that affect recognition improves markedly between the ages of three to eleven years of age. It is important to note, however, that the recognition of specific categories of emotion involves more than visual recognition and includes language processes as well. The importance of language development helps account for the chronological development of this capacity.

In an attempt to integrate what has been stated above one sees that the capacity to encode unfamiliar faces so that they become familiar as well as the ability to perceive emotion are commonplace human capacities. These capacities also have a developmental history in that as the infant becomes older and approaches adulthood this capacity increases. This may occur in conjunction with other cognitive developments as suggested by Davids. (Also see Goldstein, 1975; Goldstein & Chance, 1980; and Valsiner, 1983.)

C. Interaction of Face and Affect Perception

Although at first glance the development of these capacities, facial recognition and affect discrimination, may appear to be parallel, it is more likely that they are inextricably bound with one another. In other words, it may be that the ability to perceive emotion in a face facilitates the capacity to recognize and recall that face and vice versa.

In an attempt to understand the overlap or integration between these two skills, Sorce and Campos (1974) did a study to ascertain how important expression is in the recognition of a face. They used Schlosberg's (1954) three-dimensional scale of affect: 1) pleasantness/unpleasantness; 2) attention/rejection; and 3) sleep/tension which enabled them to have a uniform scale for the rating of facial expressions. The photographs presented to adult subjects were either in positive or negative photographic form on the assumption that recognition of facial expression would be facilitated in the positives and interfered with in the negatives. Sorce and Campos' hypothesis was that if facial expression is interfered with facial recognition should be impaired and, vice versa, if facial expression is unimpaired then facial recognition should be easier.

Although their findings indicated that the ability to perceive pleasant/unpleasant and sleep/tension dimensions were indeed associated with recognition accuracy, this accounted for a small amount of variance in their groups, leaving a large amount (from 72 to 84%) unaccounted for. Sorce and Campos say, "The inability of these dimensions to account for the major portion of variance suggests the possibility that another variable, or a combination of other variables (both emotional and nonemotional), might prove to be more important parameters of facial recognition" (p. 81).

D. Summary

Thus far, we have considered different aspects of the problem of understanding the human capacity to 1) recognize and recall familiar faces, and 2) decipher emotion. The probability that there is a strong link between these skills has also been entertained. However, it is still clear that it is not known how these capacities develop to add to our understanding of this behavior. It makes sense to investigate the neuro-anatomical locus of this function. If this function is cortical rather than subcortical in nature, the possibility of cerebral asymmetry is suggested. Does the mechanism for processing emotion rest in one hemisphere in particular, in neither, or in both?

HEMISPHERE ASYMMETRY

A. Anatomical Data

The initial studies of the differential effects of anatomical lesions by Broca (1863) were seminal in creating the study of hemispheric asymmetry. Although Broca's discovery was more properly in the domain of clinical research, it stimulated investigation of the gross anatomy and the cytoarchitectonics of the cerebral hemispheres in general, and eventually in the brain as a whole. While there has been some evidence in the past 125 years (see Galaburda, LeMay, Kemper, & Geschwind, 1978; Witelson in Segalowitz, 1983) of anatomical asymmetry, the recent upsurge in research was stimulated by the findings of Geschwind and Levitsky (1968), which confirmed differences in size between the right and left planum temporale of the cortex.

Geschwind and Levitsky were able to document that the left planum temporale was larger than the right in 65% of their 100 adult brains; the left was approximately one-third larger in area and one centimeter longer than the right planum temporale. Chi, Dooling, and Giles (1972), Wada (1969), Wada, Clark, and Hamm (1975), Wada and Davis (1977), and Witelson and Pallie (1973) extended these findings of anatomical differences to include infants and fetuses. Following Geschwind and Levitsky (1968) most of

the inferences made with regard to this morphological asymmetry have to do with human language. Also, Witelson (1985a) has found the mid-sagittal area of the corpus callosum in humans to be larger in left- and mixed-handers than in right-handers. She suggested that there may be an association between a greater anatomical connection between the cerebral hemispheres in left- and mixed-handers and their greater bihemispheric involvement in various cognitive functions. (For important exceptions in humans see Geschwind & Behan, 1984. For related non-linguistic work with non-humans see Denenberg, 1984; Diamond, 1984; Nottebohm, 1984; Gerendai, 1984; Glick & Shapiro, 1984; Goldman-Rakic & Rakic, 1984.)

There are other anatomical data which show a wider, more protruding right frontal lobe (right frontopetalia) in contrast to a greater protrusion of the left lobe in the posterior portion of the brain (left occipital petalia) in adults, children, fetuses and prehistoric human skulls (LeMay, 1976, 1977; LeMay & Geschwind, 1978, 1981; LeMay & Kido, 1978 in Best, 1985). While Best (1985) uses these data to fortify her theory of a "right-to-left gradient in the embryologic emergence of the cerebral hemispheres" they may also be considered when trying to explain the emergence and development of functional asymmetries. Is brain development isomorphic

with behavioral development? This will be considered again in the discussion.

B. Clinical Data

As previously discussed, the idea that there are specific areas of the brain which are specialized for function is not a new one. (For a review of the early research, see Gibson, 1962.) Hughlings Jackson in 1860 was the first to show that a diseased hemisphere affected involuntary movements of the contralateral hemisphere. He went on to describe, in some detail, language imperceptions ("word-deafness" and "word-blindness") which resulted from epileptic seizures affecting the left half of the brain (Jackson, 1894, 1925).

Much of the recent work on lateralization got its major impetus from the work of R.W. Sperry and his colleagues. The experimental surgical technique known as cerebral commissurotomy, which is the severing of the cerebral commissure so that the right and left hemispheres of the brain are distinct and discrete entities, was used primarily for control of epilepsy. Sperry and his colleagues studied patients before and after commissurotomy to investigate the sensory and cognitive capacities of each hemisphere separately.

The visual system is neurologically wired so that the rule of contralaterality applies. Specifically, visual

stimulation to the right of central fixation is registered initially in the left cerebral hemisphere while the opposite is true for visual stimulation to the left of fixation. This set of events makes the split-brain patient a "natural" subject for the study of cerebral asymmetry; the transmission of visual information between hemispheres is interrupted due to the severing of the callosum. Many studies were done comparing and contrasting behaviors produced in relation to the stimulated hemisphere (Sperry, 1968a, 1968b; Sperry, Gazzaniga, & Bogen, 1969). The main focus of their findings centered on hemispheric specialization for language. However, some of this early work is germane here. For instance, Gazzaniga, Bogen, and Sperry (1965) demonstrated superiority in the right hemisphere for the capacity to visualize spatial relations. Levy, Trevarthen, and Sperry (1972) have also found evidence, using commissurotomy patients, that the right hemisphere is involved in face perception. However, they also suggest that both hemispheres are capable of facial perception. Milner and Taylor (1972) describe evidence of superiority in the right hemisphere for memory of spatial patterns in perception.

These studies are important because of the long-standing view of the superiority of the left hemisphere

for complex cognitive processes. This view was based upon the observation that injuries to the left hemisphere in adults would lead to loss of speech (aphasia), whereas speech disturbance would rarely be exhibited after right hemisphere injury; these findings pertain primarily to right-handed people. As Milner (1971) pointed out, it soon became the commonly accepted dogma that the left hemisphere was dominant for all complex cognitive processes with the right being less important, except for perhaps elementary sensory and motor functions. However, with more sophisticated observational procedures and experiments to follow, this traditional view of right hemisphere inferiority has been largely rejected. Although these early clinical researchers and their findings do not specifically refer to cerebral specialization for the perception of emotion, to a large extent the clinical model provides the backdrop, both conceptually and methodologically, for this field of research.

Limitations

There are serious limitations though to the use of clinical data. Due to the uncontrolled nature of their collection they do not easily answer questions regarding boundaries and overlaps between areas. The brain is too complex an organ to be able to say with certainty that a particular, diseased area is specifically responsible for

a behavioral dysfunction. A related problem is that different sections of the brain are probably not totally function-specific, so that lesioned areas affect several functions differentially, with a one-to-one relationship between brain and behavior remaining unclear. Of equally important concern is the concept of compensation. It is most likely the case that when one region or area of the brain is damaged another compensates, at least partially, so that behavior is minimally disrupted. Inferences regarding the role and magnitude of the role of the damaged part in a particular behavior remain confounded.

The concepts of attention and suppression resulting in use and underuse are also suggestive of the idea that parts of the brain develop different functions at different rates. One model suggests that different cerebral areas can be activated if the need arises thus influencing the expression of asymmetry (Kinsbourne & Cook, 1971). Another problem with the use of clinical data is how secure one can be about actual loss of function. For example, if the behavior is not assessed soon after the sustained trauma, it may be difficult to state with certainty whether or not there has been some recovery of function which interferes with the judgment of immediate functional loss (Witelson, 1977).

C. Experimental Data with Normals

1. Children and Adults

Research in this area has proliferated. Many studies have been done in multiple areas of human behavior to determine the role of the right versus left hemisphere in normal functioning. Harnad (1972) studied lateral eye movements (LEMs) and found more left LEMs (which suggests greater right hemisphere involvement) when subjects were asked questions that tapped creative thinking in the field of mathematics. (Also see Ross & Turkewitz, 1981, 1982; Turkewitz & Ross, 1983.)

Dee and Fontenot (1973) demonstrated that there is dominance of the right hemisphere for the perception of stimuli with a low verbal association. They were also able to show that the right hemisphere's superiority for the perception of complex forms is not purely a perceptual process but rather a difference in memory as well. Pennal (1977) has demonstrated that there is cerebral asymmetry in the task of color discrimination with the right hemisphere being dominant. Hines (1975, 1978) demonstrated hemispheric asymmetry depending on whether the stimuli were words or shapes. Klein, Moscovitch, and Vigna (1976) also found a relationship between words and faces and hemispheric superiority.

A series of experiments was done with normal subjects using the methodology of dichotic listening. This method lends itself well to the study of hemispheric differences because each ear projects to both hemispheres. And, when each ear is presented with different stimuli at the same time (dichotic presentation), the information presented to the ipsilateral channel is suppressed (Rosenzweig, 1951). Verbal responses thus should more clearly reflect right ear input. Since the left hemisphere will "speak" only about information it has received contralaterally, information from the left ear will have been suppressed. Although the auditory pathways are subcortical, and thus not interfered with in either split-brain subjects or normals receiving dichotic stimulation, transmission of information between the hemispheres is disrupted, at least temporarily.

It has been shown in fact that the right ear has an advantage for verbal material such as words and consonants (Bryden, 1966; Kimura, 1973), while the left ear appears to have an advantage for the recognition of nonverbal stimuli (Curry 1967; Kimura, 1967).

The issue of subcortical processing has relevant implications for the experimental study of asymmetry in general, and lateralization for processing of emotion in particular. The possibility that certain forms of

processing do not occur in the cortex but rather sub-cortically suggests that experimental manipulations aimed at uncovering cortical activity have to be revived. This will be considered further in the discussion.

In two other important papers, Lewandowski (1982) and Piazza (1977) were able to demonstrate that children also demonstrate hemispheric asymmetries in several sensory dimensions (manual, visual and auditory) and that they are established in some instances by three to five years of age and very reliably by seven years of age. Lewandowski, using both a dichotic listening task and a visual split-screen arrangement, tested boys between the ages of 7 and 16 years and found almost uniform asymmetry on both tasks. Piazza tested both boys and girls (3, 4 and 5 years) on a dichotic listening task as well as a finger tapping experiment. Lateralization was found for both experiments in all age groups. These findings lend support to the need for a developmental approach in order to clarify the ontogeny of hemispheric lateralization.

2. Hemispheric Dominance or Advantage?

There is a complex issue subsumed in the study of asymmetry about which there is a fair amount of controversy. Specifically, is either hemisphere really dominant for responding to particular stimuli or rather does one or the other hemisphere have an advantage depending upon the

form of processing required. One can consider the differing superiorities of each hemisphere for specific tasks and functions, or one can consider the form (analytic versus holistic) of the mental processing rather than the content of the stimulus processed (Bever, 1975). The notion of competitive hemispheric processing therefore gives way to the idea of complementarity. It can be said that the two hemispheres exist in a reciprocal relationship, basically complementing one another. More appropriate terminology therefore when discussing lateralized functioning might be that of lateral advantage with relation to a particular type of processing. By that it is meant that the right or left hemisphere is better able in the form of processing a particular skill required rather than being the sole actor in these human behaviors.

My aim in raising this issue is simply to alert the reader to the fact that these questions have been raised as attempts to broaden our understanding of the complexity of this body of research. The attempt to demonstrate cerebral dominance for music illustrates this concept. Trained musicians have a left hemisphere advantage when identifying music while untrained subjects demonstrate a right hemisphere advantage on the same task (Bever & Chiarello, 1974). In a related paper, Goodglass and Calderon (1977) studied the processing of verbal and tonal

material in musicians to determine if the form of the stimulus as well as musical sophistication of the subject determines hemispheric superiority. They quoted Bartholomeus (1974) who found left ear superiority for music in musically sophisticated subjects. They also quoted Bogen and Gordon (1971), who pointed out that musical competence may move the center of processing of melodies to the left hemisphere.

As Goodglass and Calderon state, "The lateralization of music remains a vexed question, involving many interacting factors." Confirmation of this point of view can be found in the work of Shanon (1984). He demonstrated complex and changing asymmetries for musicians and no asymmetry for nonmusicians when making aesthetic judgments of music.

3. Infants

Segalowitz and Chapman (1980) presented findings which show that premature neonates exhibit cerebral asymmetry for speech in that there was a reduction in right limb movement after exposure to speech stimuli compared to controls who were exposed to orchestral music or no patterned stimuli.

Molfese (1975) did a series of experiments using evoked potentials to measure hemispheric differences in

responding to music and speech in infants. He found greater amplitude of certain components of the cortical evoked potentials from the left hemisphere in response to speech and from the right in response to music or pure tones.

Entus (1977) combined frequency of high amplitude sucks as a response measure in a dichotic listening task and found recovery of sucking greater in response to a change in verbal stimuli to the right ear with greater recovery in response to a change in music stimuli to the left ear. Glanville, Best, and Levenson (1977) using a cardiac dishabituation procedure which will be reviewed later also found the expected left hemisphere/language -- right hemisphere/music relationships.

These studies suggest functional asymmetry in young infants under very specific experimental conditions, namely auditory stimulation. Implications of these findings for the research reported herein will be considered in the discussion. For the moment, it is important to note that asymmetries can be found in infancy for language and music.

Can this be found for faces and emotion?

D. Lateralization of the Perception of Faces and Affect

1. Face Perception

There is a large body of research which indicates the likelihood of cerebral specialization for the task of facial recognition and, within that function, that of affect recognition. DeRenzi, Faglioni, and Spinnler (1968) pointed out that adult patients with unilateral brain damage to the right hemisphere have a greater impairment of facial recognition, particularly of unfamiliar faces, than those with impairment on the left side. Benton and Van Allen (1968) and Warrington and James (1967) also provided data which suggest a clear association between damage to the right hemisphere and impaired facial recognition.

Yin (1970) reinforced the argument for right hemispheric specialization for facial recognition, also with brain damaged subjects. He added the variable of inverted-face recognition and showed that while right posterior injury affected upright-face recognition, patients with such disorders did better than those with left posterior damage on recognition of inverted faces. This led Yin to suggest that the right hemisphere has a "material-specific" sensitivity to facial recognition tasks. Leehey, Carey, Diamond, and Cahn, (1978) corroborated Yin's findings using normal subjects with

tachistoscopic presentation of similar stimuli. However, Benton (1980), DaMasio, Damasio, and Van Hoesen, (1982) and Meadows (1974) give evidence that only bilateral lesions result in impaired recognition of familiar faces (prosopagnosia).

Ellis and Shepherd (1975) did a study to elaborate on Yin's proposal that, although the right hemisphere is dominant for the processing of upright faces, when inverted faces are presented they will be better recognized when presented to the right visual field, i.e., the left hemisphere. Ellis and Shepherd were able to replicate left visual field (LVF) superiority as predicted for upright faces, but they also found the same to be true when inverted faces were presented to the right and left hemispheres. In other words, the right hemisphere is also superior in the processing of inverted faces. Their conclusion was, "one way of accounting for the data is to suggest that the hypothesized face specific recognition system is not orientation sensitive. Alternatively, the results could be accounted for by invoking the idea that the right hemisphere is simply better at recognizing any complex patterns which require a high level of integration in order to be apprehended" (p. 6)

Hilliard (1973) studied normal subjects to test for hemispheric laterality effects on facial recognition

tests. He found that performance was significantly better when faces were presented to the left visual field or right hemisphere than vice versa. As he stated, "a significantly greater number of Ss showed superior recognition of faces in the left visual field than in the right. Thus, a hypothesis which was initially suggested by the results of neuropsychological studies carried out with brain-injured subjects has been confirmed utilizing a sample of subjects with intact central nervous systems" (p. 254).

Leehey and Cahn (1979) extended our understanding of hemispheric differences with regard to recognition of faces by showing a right hemispheric superiority for the recognition of familiar faces as well as unfamiliar faces. They presented subjects with words and faces and were able to show the predictable left hemisphere advantage to words and right hemisphere advantage to perceptions of faces. Geffen, Bradshaw, and Wallace (1971) have been able to display the ability of normal subjects to respond "same" or "different" to a pair of faces when displayed tachistoscopically and their findings differ according to the visual field to which the stimuli are presented. Finlay and French (1978), using signal detection theory, also presented findings which support the proposition that the hemisphere to which the stimulus is presented will affect

the likelihood of facial recognition. They too found right hemisphere superiority.

A paper by Marzi and Berlucchi (1977) helps to validate the notion of the complexity of the stimulus accounting for right hemisphere superiority. The experimental manipulation was the tachistoscopic presentation of faces to the periphery of the foveal area which forced the subjects to adopt a single feature detection strategy for facial recognition. Their results show a right visual field (left hemisphere) superiority for accuracy of recognition of famous faces. Marzi and Berlucchi argued that the recognition of famous faces relies on analysis of one salient discriminable physiognomic feature, rather than the complex of facial features more usually processed and which is the standard arrangement required of most of the other studies discussed (see Galper & Costa, 1980; Patterson & Bradshaw, 1975; Ross & Turkewitz, 1981, 1982). It is their point that this form of single feature detection engages the left hemisphere and is a specific form of processing faces.

This returns us to a point that was made earlier which is that lateralization is not just a function of the nature of the material being processed but also the type of processing required. For example, Patterson and

Bradshaw (1975) suggested that the analytic versus holistic dichotomy in cognitive processing may be a more basic and interesting distinction to make when discussing cerebral lateralization than that of the more standard language/visuospatial dichotomy. They based this hypothesis on their experiment which showed that, although there is in general a right hemisphere advantage for facial recognition, when the recognition task was whether two faces were the same or different, the left hemisphere had the advantage when the test stimulus differed from the standard stimulus on only one feature. In other words, when the task allowed an analytic strategy, the left hemisphere showed a processing advantage; when a more holistic response was required the right hemisphere was superior. (See in this context the work of Bever & Chiarello, 1974.)

Children and Infants

Marcel and Rajan (1975) added to this body of literature by pointing out that children who are tagged as good and poor readers did equally well on a facial recognition task (demonstrating a right hemisphere advantage), while those who were designated as good readers showed a greater left hemisphere superiority when presented with five-letter words. Their conclusion is that hemispheric specialization for visuospatial processing or facial recognition is independent of that of verbal processing

and therefore the hemispheric capacities are presumed to be independent as well.

Young and Ellis (1976), also using children as subjects, found right hemisphere superiority on a facial recognition task in five-, seven- and eleven-year-olds. Broman (1978) using manual reaction time as the dependent variable found right hemisphere superiority for face discrimination in seven-year-old boys. However, on a similar task McReynolds and Jeeves (1978) failed to find significant lateral differences with seven- to eight-year-olds. There is a fair amount of uncertainty and contradiction within this body of research which warrants further study.

For example, several studies have shown that the physical characteristics of stimulus presentation as well as the specific information processing task required will affect hemispheric dominance (Galper & Costa, 1980; Sergent, 1982; Sergent & Bindra, 1981). The point is made that although the task may ostensibly be facial recognition there are many facets of the procedure which can alter the experimental outcome, such as speed of presentation, exposure time, level of discrimination, section of face presented. These considerations have important meaning when considering studies with infants. To date, there are only two studies of lateralization for faces using infants.

Witelson and Barrera (cited in Best, 1985) studied three-month old infants. They stated that their data support the position that hemispheric asymmetry for processing faces exists in infants. Also, Mathivet and DeSchonen (unpublished), studying infants, reported similar findings and both studies assert right hemisphere superiority in the processing of faces in infants. Their research, data and assertions will be considered in the discussion with relation to the research described in this thesis.

In a series of papers (Ross & Turkewitz, 1981, 1982; Turkewitz & Ross, 1983), an argument is made for the development of strategies applied to the task of facial recognition. Ross and Turkewitz stated that development occurs within subjects such that an initial LVF advantage gives way to a RVF advantage and then returns to a LVF advantage as integration occurs. In other words, depending upon which point one taps into experimentally on facial recognition tasks, the data will reflect nonuniform hemispheric advantage. These strategies are also meaningful in the context of hemispheric asymmetry in the processing of emotion.

2. Perception of Emotion

Suberi and McKeever (1977) also demonstrated non-uniform hemispheric advantage depending upon whether a

subject is looking at extremely emotional faces as opposed to faces which are more emotionally neutral. Their results showed that subjects who memorized emotional faces on tachistoscopic presentation had faster discrimination of those faces when they were presented to the LVF rather than the RVF. Subjects whose test stimuli lacked emotional expression still showed LVF superiority or right hemisphere processing advantage although significantly smaller than that of the subjects memorizing emotional faces.

There are two interesting papers by Campbell (1978, 1979) in which she was able to show that judging emotion increases right hemisphere advantage for facial recognition. It is the requirement of organizing the individual parts of the face into an emotionally significant gestalt that engages the right hemisphere. As Campbell says, "this advantage due to emotional salience may be independent of the proven perceptual advantage of right hemisphere processing." In further exploration of these findings Campbell did another set of experiments which indicated that there are also expressor asymmetries which exist so that the more intense emotion is most often expressed by the left side of the face.

Heller and Levy (1981) confirmed Campbell's findings in that they found happiness more often expressed on the

left side of the face. Although Campbell was unable to offer any sound neurological support for this finding, she made the suggestion (based on Goldstein, 1939) that there is a general right hemisphere sensitivity to emotion. Gilbert and Bakan (1973) showed, by presenting photographic reversals of faces to young adult subjects, that left visual field perceptual bias accounts for the processing of faces. It is right hemisphere specialization for facial recognition rather than any inherent information in the right half of the face which accounts for this asymmetry according to Gilbert and Bakan.

This possibility of left-sided expressor superiority as perhaps the functional reciprocal of the right hemisphere displaying superiority when processing complex emotional expressions is evident in the findings of Bear and Fedio (1977). Epileptics were administered questionnaires assessing psychosocial behavior. They found that emotional intensity and emotional "styles" are different for right versus left temporal epileptics. Right temporal epileptics gave more uninhibited emotional responses in contrast to left temporal epileptics whose answers were more ideational when responding. Although a clinical population, their findings are relevant for the hypothesis that there is hemispheric asymmetry for the expression of affect.

Ekman, Hager, and Friesen (1981) demonstrated a stronger left facial asymmetry for deliberate facial actions in normals. Borod and Caron (1980) were also able to demonstrate facial or expressor asymmetry ("facedness") such that left-facedness was found for 77% of right handed subjects and 65% of left handed subjects. Sackeim and Gur (1978) and Sackeim, Gur, and Saucy (1978) showed that left side composites were rated more emotionally intense than their mirror right side composites. Moscovitch and Olds (1982), using both field and laboratory techniques, reinforced the finding that emotions are displayed more strongly on the left side of the face than the right in right-handers. Rubin and Rubin (1980) had earlier reported similar results with eight to ten year old children. The inference from these data is that expressional asymmetry does exist and that it is mediated by the right hemisphere.

3. Is the Perception of Specific Emotions

Lateralized?

Given that perhaps there is right cerebral hemispheric superiority for the processing of facial expression as well as a left hemisphere processing advantage when particular aspects of emotional facial stimuli are presented, an interesting question is raised.

Is there a differential processing capacity of the right and left hemispheres when it comes to the perception of specific emotional stimuli? Reuter-Lorenz and Davidson (1981) performed an experiment to try to answer this question. Their results showed that in adults reaction time is faster when a happy expression is presented to the RVF and a sad expression is presented to the LVF. Reuter-Lorenz and Davidson stated, "the data support the hypothesis of differential hemispheric specialization for positive and negative emotion."

In an earlier note, Harman and Ray (1977) did a study in which subjects were asked to generate positive and negative emotional stimuli. Analyses of variance using the ratios of right hemispheric EEG power to left hemispheric EEG power were performed to determine hemispheric involvement in responding to emotion. Their results indicate an increase in power for positive affect and a decrease in power for negative affect in the left hemisphere. However, the right hemisphere showed no significant change in power regardless of the variety of the emotional stimuli. Harman and Ray conclude that there is greater response in the left hemisphere to emotional stimuli altogether, whereas the right side of the brain seems to remain, in their words, more calm and balanced in the face of emotional stimulation.

However, Schwartz, Ahern, and Brown (1979) used electromyograph (EMG) readings to substantiate the hypothesis that there is hemispheric specialization for the responding to and demonstration of emotion. EMG values indicated greater right facial muscle activity (left hemisphere) in response to positive emotional stimuli; and greater left muscle activity (right hemisphere) in response to negative emotional stimuli. Sackeim, Greenberg, Weiman, Gur, Hungerbuhler, and Geschwind (1982) found that cerebral hemispheric lesions, hemispherectomy, and epileptic foci were correlates of pathological laughing and crying. Basing their findings on the theory of neurological disinhibition or excitation, Sackeim, et al., suggest that pathological laughing is associated with insult to the right hemisphere and pathological crying is associated with insult to the left hemisphere. They consider that the basic relationship is between the right hemisphere and negative emotions and the left hemisphere and positive emotions.

In a related finding, Halliday, Davison, Browne, and Kreeger (1968) found more positive results to electroconvulsive therapy for depression when administered to the right cerebral hemisphere rather than to the left. The relationship between specific forms of affect, for example, happiness versus sadness, and the specific

hemisphere doing the processing is not clear. Evidence has been cited which tentatively indicates that perhaps the right hemisphere more readily responds to sadness while the left hemisphere has the advantage in responding to happiness.

4. Developmental Evidence

Davidson and Fox (1982) used EEG recording to examine the response of ten-month old infants to emotional stimuli. They were able to show that at least in the frontal area, there was greater EEG power in the left than in the right hemisphere when happy faces were presented to that hemisphere. [However, there is some controversy regarding the probability that EEG studies accurately reflect or measure mental activities (Davidson & Ehrlichman, 1980; Ehrlichman, H., & Weinberger, A., 1979; Gevins, Doyle, Schaffer, Callaway, & Yaeger, 1980; Ornstein, Johnstone, Herron, & Swencionis, 1980).] The importance of their study lies in the fact that it may indicate that there is some lateralization for the processing of emotion within the first year of life.

E. Conclusion

The preceding studies can be summarized in the following manner: Human beings are adapted to the task of recognizing faces, and this seems to be a rather universal function with very little difference found in cross-cultural comparisons. This ability does not appear de novo in adulthood, but rather is present very early in life and may become refined as the individual gets older. Responding to facial emotions is also highly sophisticated in humans, and as with general facial recognition, is evidenced in infancy and childhood and develops as the individual gets older. There is probably some integrative aspect of both facial and affect recognition so that the more clear the emotional expression is on the face, the easier the facial recognition.

The human brain with its two discrete hemispheres clearly shows lateralization for many tasks and leads one to the conclusion that each hemisphere has specific functional advantages with regard to certain types of cognitive processing. The left hemisphere seems to have an advantage when responding to complex analytic and verbal tasks while the right hemisphere appears to have an advantage with tasks that require holistic, nonverbal visuospatial processing.

The right hemisphere appears (although there are conflicting data) to be the half of the cortex with the advantage in processing faces and affective stimuli. It is important to note, however, that when the task demands analytical reasoning such as discrimination of only one aspect of a face, the left hemisphere has the advantage.

Is it reasonable to assert that the right hemisphere more readily processes facial/affective information? There is development of the capacity to process visual, facial, and affective stimuli such that the infant seems to display the rudiments of this capacity while the adult displays the refinements. However, it has not yet been ascertained which, if either, hemisphere in the infant is actually doing the processing of affective stimuli. Without any preconceived convictions as to which hemisphere performs this processing task, especially given the complex data already reported, the following questions arise: 1) Is there hemispheric asymmetry in the processing of emotion by infants? 2) If so, does asymmetry refer to the fact that one hemisphere clearly and always has a processing advantage? Or, possibly, is each hemisphere differentially involved so that in some circumstances one hemisphere has an advantage and in some the other hemisphere does?

These general questions form the basis of the experiments and hypotheses which follow.

EXPERIMENTAL DESIGN

A. Explication

Studies indicate that six-month old infants are appropriate subjects for further exploration of the development of hemispheric asymmetry. Cohen and Strauss (1979) indicated that 30-week old infants are capable of displaying concept acquisition which is clearly different and superior to that of babies tested under the same conditions at 24 weeks of age. This finding suggests that babies by 24 weeks enter a new stage of cognitive development and therefore might be appropriate subjects for the task required in assessing cerebral dominance for the category "facial expressions." Cornell (1974), and Fagan (1972, 1973, 1977) also found that by six months infants are more cognitively sophisticated than earlier and perform better on facial recognition tasks. In addition to this increased cognitive development, six-month olds have a highly developed visual system as well as being more tractable than younger infants (Dobson & Teller, 1978).

Research in which slides of adult faces expressing specific emotions were presented to opposite sides of the visual field in six- to seven-month old infants is reported here. It was expected that if asymmetry exists

for the processing of faces and emotion this design might produce a differential rate of response to the visual stimuli in these infants. However, the possibility of no asymmetry had to be entertained because of the possibility that asymmetry develops over time and is not functionally present in infants. The procedure employs the method of habituation and dishabituation to experimental stimuli, and cardiac monitoring as a measurement tool.

Habituation

Before describing the methodology, it is important to present the arguments for the use of the habituation/dishabituation paradigm and change in heart rate as the dependent variable. The habituation procedure is one where the subject, in this case an infant, is repeatedly presented with the same or similar stimuli until orienting or other response indicative of attention-paying declines. A novel stimulus is then introduced and the response to it is recorded. The decrease of responsiveness to the familiar stimulus is called habituation, and the increased response to the novel stimulus is called dishabituation. The relationship between the novel and habituated stimuli is, to some extent, the critically informative component of an experiment using the habituation/dishabituation paradigm. Responding is therefore to the unique information available in the novel stimulus. One can more

clearly assess, by having this information stand out in relief as it were, what is salient for the subject.

Cardiac Change

One manner of measuring habituation is from physiological monitoring concurrent with the habituation/dishabituation procedure. A useful and also previously used physiological measure is cardiac rate change. In this case, in the attempt to discern if either cerebral hemisphere is dominant in the processing of affect, one looks at the heart rate with relation to the hemisphere to which the stimulus is being presented.

In a series of papers by Bridger (1962), Bridger and Reiser (1959), and Bridger, Birns, and Blank (1965) a very clear correlation developed between the change of heart rate and change in other behavioral indices in neonates which helps to form the rationale of the use for this paradigm. In work with older infants, Campos, Emde, Gaensbauer, and Henderson, (1975) and Provost (1979) showed that heart rate and behavior do interact so that heart rate acceleration/deceleration correlates neatly with overt behavior and emotional states. In particular it has been shown that there will be heart rate deceleration when the infant is presented with a novel stimulus and heart rate maintenance or acceleration when

habituation to repeated stimulation occurs (Campos & Johnson, 1966; Graham & Clifton, 1966; Lewis, 1971; Lewis, M., Kagan, J., Campbell, H. & Kalafat, J., 1966; Schwartz, Campos, & Baisel, 1973).

Glanville, Best, and Levenson (1977) successfully used heart rate change as the dependent variable in assessing cerebral asymmetry for language in infants. Their raw data were comprised of difference scores between pre- and post-stimulus heart rate. The use of cardiac change reported in the experiments that follow is, to a large extent, based on the Glanville, et al. design. Using a dichotic listening test they habituated cardiac responses of three-month old infants to either speech syllables or music notes. The test trial (10th trial) was a novel stimulus in the same category as the habituating stimuli presented to the right or left ear. They found a left ear/music and right ear/language effect.

Tachistoscopic Split-Screen Stimulus Presentation

Tachistoscopic presentation remains a critical component of the experimental design which follows. By controlling and limiting the duration of stimulus exposure one is confident that eye movement after fixation will not occur in relation to the stimulus presentation; and by controlling its retinal placement and therefore its projection, certainty as to which cerebral hemisphere the

image is being projected is secure (Harvey, 1978; Haun, 1978). Sergent's (1983) major review of the topic asserts that the quality and discriminable aspects of a tachistoscopic test stimulus can have a major effect on responding (for example, see Moscovitch, Scullion & Christie, 1976; Rizzolatti & Buchtel, 1977). The physical characteristics of the stimulus must be kept in mind when assessing hemispheric responding to it. This will be explored further in the discussion.

B. Hypotheses

Relating habituation of cardiac change to tachistoscopic split-screen stimulus presentation should facilitate understanding of the role of the hemispheric lateralization response of infants to pictorial representations of facial expression of emotion.

The assumptions or hypotheses tested here are that: 1) standard split-screen technique can be used to assess asymmetry in infants; 2) heart rate deceleration in response to novel stimuli in infants is an appropriate dependent variable when measuring asymmetry; and 3) the magnitude of responding (heart rate deceleration) to affective stimuli should be greater in one hemisphere if there is asymmetry for the responding to and processing of these stimuli; and 4) there should be a significant

interaction between hemisphere and the content of the dishabituating stimulus (described in the method section) if there is asymmetry for processing affective stimuli.

A. EXPERIMENT 1

1. Subjects

Twenty-two full-term infants born without complications, as indicated by discharge summaries at a major tertiary care hospital in New York City, were used as subjects. Their parents were contacted when the babies reached the age of six months. The age range of subjects was six to seven months with a mean age of 6.4 months. The parents received an introductory letter (see Appendix A) and a follow-up telephone call. Approximately 90 parents were contacted; therefore, some self-selection was involved. The subjects were primarily from a white, middle and upper middle class socio-economic group. Subjects' mothers were questioned in order to eliminate those with complications after discharge.

2. Procedure

The stimuli consisted of a subset of photos of the Pictures of Facial Affect developed and standardized by Ekman and Friesen (35mm black and white slides).² The

² Ekman and Friesen determined reliability on both forced choice and rating scales paradigms with equal numbers of male and female U.S. born college students. All photographs in the set were judged as depicting the intended emotion by at least 70% of raters. The slides chosen for this study were rated correctly by at least 90% of the judges.

stimuli selected for this study were happy, sad, and surprised. They were selected since they represent three of the five universally experienced emotions (Ekman, et al., 1969; Izard, 1971; Saha, 1973) as well as having been shown to be discriminable by neonates (Field, et al., 1982). The findings by Davidson and Fox (1982) of hemispheric asymmetry for the specific expressions happy and sad reinforce these choices.

In order to prevent the stimulus from impinging on both visual fields simultaneously, they were rear-projected by a Nikon slide projector onto a screen and exposed for 300 milliseconds. They were projected to the right or left of a central fixation point (a blinking red LED). This duration is based on the findings of Aslin and Salapatek (1975) and Salapatek, Aslin, Simonson, and Pulos (1980) that under experimental conditions utilizing central fixation as baseline it could take as long as 300 milliseconds for a saccade to be initiated in response to visual stimulation. Also, Moscovitch, Scullion, and Christie (1976) used a 300 millisecond time interval in a related lateralized experiment with adults and found evidence indicating that this duration is a reasonable amount of time before the production of ocular saccades. It is likely that the latency in infants is at least as long.

During the experimental session the heart rate of the subject was measured continuously with a direct writing, standard electrocardiograph (Marquette) using leads attached to both wrists and ankles. The electrocardiograph was modified such that one channel recorded stimulus onset and offset in parallel with the second channel which monitored heartrate. The electrocardiograph and Nikon slide projector were connected to a Hunter timer (Model No. 111-C) so that the timer initiated pen movement simultaneously with the opening of a shutter (Uniblitz Electronic) affixed to the slide projector. A room air conditioner was continuously on and provided a constant low level of noise which also effectively masked street sounds.

Subjects and their parent were greeted at the door of the experimental room by the experimenter. The procedure was explained to the parent in order to obtain informed consent. Electrodes were then affixed to the infant with rubber wristlets and anklets and contact with the skin was made with EKG lotion.

Subjects were seated on mother's lap in a three-sided black booth (61 cm wide X 61 cm deep X 122 cm high) so that their eyes were approximately 50 cm from the screen at this distance. Neither mother nor experimenter were blind to the conditions of the experiment. This can, in

future, be easily accomplished with catch trials, independent observer, and mother's view of stimuli being obstructed. A visual angle of 5 degrees was subtended from the fixation point to the edge of the stimulus. The faces on the screen measured 13 cm in length, subtending a visual angle of 15 degrees, and 18 cm in width, subtending a visual angle of 21 degrees. Stimuli were presented serially, one at a time. Central fixation was determined by the experimenter seated directly beneath the screen observing the subject through an observation hole (.6 cm in diameter) along the same plane as the LED but beneath the screen. Prior to any one stimulus presentation and after ascertaining central fixation, the experimenter opened the shutter with a foot switch. If the baby shifted gaze during a particular stimulus presentation, the stimulus was re-introduced when central fixation next occurred. Inter-trial intervals ranged from 3 to 15 seconds. The mode for subjects to resume central fixation was 5 seconds.³

Testing consisted of two sets of 30 trials each. One set of slides was presented to the right and the other to the left visual field. Each set contained ten photographs

³ The problems of visual angle, slide projector sound, and non-blind procedure will be considered in the results and discussion sections.

of men and women with happy faces, ten photographs of men and women with sad faces and ten photographs of men and women with surprised faces. Each set was broken down into six habituation subsets so that four photographs of different models with the same expression were shown sequentially (habituation process) followed by a fifth (different model) with a different facial expression (dishabituating stimulus). For example, there were four happy faces followed by a fifth which was sad, and four surprised faces followed by a fifth which was happy, and so on (see Table 1, page 52). Order of the photographs remained constant so that presentations to the RVF and the LVF were identical for all subjects. One half of the subjects received the stimulation to the RVF first and the other half to the LVF first. There was a variable time out between visual field stimulation. The total time required for the entire experiment ranged from about 30 to 50 minutes.

3. Dependent Variable

The dependent variable was heart rate change as measured pre- minus post-stimulus presentation.

4. Scoring of Heart Rate Change

The raw data were scored by measuring the span of the six heart beats immediately preceding the stimulus onset

Table 1
Presentation of Stimuli in Experiment 1

Trial	Subset					
	1	2	3	4	5	6
1	Surprised					
2	Surprised					
3	Surprised					
4	Surprised					
5	Sad					
6		Surprised				
7		Surprised				
8		Surprised				
9		Surprised				
10		Happy				
11			Sad			
12			Sad			
13			Sad			
14			Sad			
15			Happy			
16				Sad		
17				Sad		
18				Sad		
19				Sad		
20				Surprised		
21					Happy	
22					Happy	
23					Happy	
24					Happy	
25					Surprised	
26						Happy
27						Happy
28						Happy
29						Happy
30						Sad

and the six beats (numbers 3 to 8) following the first two beats after stimulus offset. The data were scored in this way because there is approximately a one-second latency in heart rate response in infants (Lipton, Steinschneider, & Richmond, 1966). Calipers were used to measure the span of the six beats before and after stimulus onset; the calipers were then applied to a rule to determine heart rate. The difference scores of heart rate before and after stimulus onset of each trial were thus obtained and provided the raw data used in the statistical analysis. Specifically, the pre-stimulus heart rate was subtracted from the post-stimulus heart rate to determine if heart rate had decelerated, accelerated or remained the same in response to stimulation.

5. Results

Repeated measures analyses of variance (Biomedical Data Processing computer program -- this program rejects any observation with missing cells thereby producing variable Ns depending on which components of the design are analyzed) were applied to the data in order to examine habituation, dishabituation, visual field and order effects. The first and last of the habituating stimulus events were compared with one another to determine if habituation had occurred. Another way of assessing the

habituation process is to compare the last of the events of habituating stimuli with the critical or dishabituating stimulus which made up the second analysis. These analyses yielded no significant results. There were no significant differences between the first and last of the habituating trials nor between the last of the habituating trials and the dishabituating stimulus.

The means of the first and second trials vs. the means of the third and fourth trials, and the means of the third and fourth trials vs. the fifth trial were also compared. Both of these ways of organizing the data were utilized since the number of habituation trials was fixed, thereby leaving one uncertain as to the stage of the process in which habituation occurred. Averaging offers the possibility of covering several critical points in time and thereby retrieving more information about the habituation process. There were no significant main effects for habituation, dishabituation, or asymmetry.

However there was a significant interaction between order of presentation to visual field and visual field (VX0) for both data sets, averaged or unaveraged. (Averaged: $N = 22$, $F(1, 20) = 4.60$, $p < .05$; Unaveraged: $N = 17$, $F(1, 15) = 7.73$, $p < .02$). Figure 1 (page 55) suggests that the significant interaction reflects the fact that when the left visual field is stimulated first

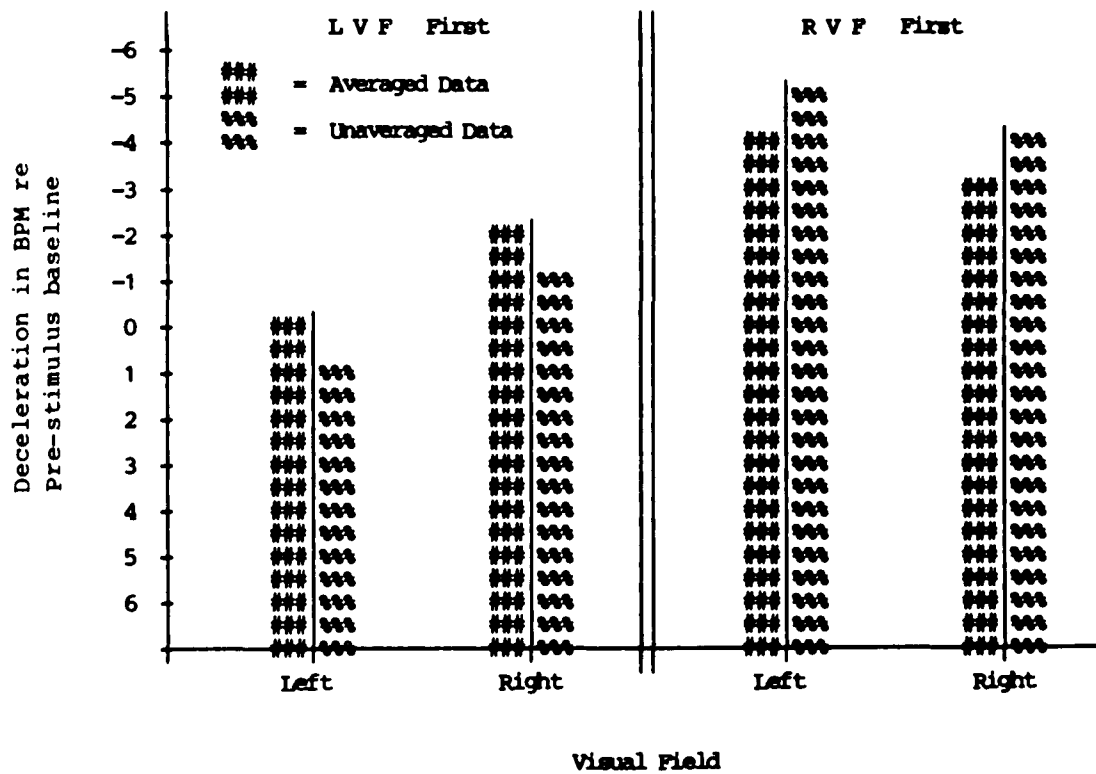


Fig. 1. Visual field x order interaction for averaged and unaveraged data for all subjects in experiment 1

there is greater deceleration response to subsequent stimulation of the right visual field whereas when the right visual field is stimulated first there is greater deceleration in response to subsequent stimulation of the left visual field. At this stage, it may be appropriate to suggest an interaction model such that the first hemisphere stimulated interacts with the second in such a way that it responds more vigorously. This has implications for asymmetry in that, under certain conditions of order of stimulation, asymmetry may be discernible.

B. EXPERIMENT 2

The first experiment raised several important questions about both the experimental task and the need to refine the distinctions between face and emotion. It is clear that one cannot state with certainty whether the failure to obtain evidence of habituation was due to face change or change of emotion. As Cohen and Strauss (1979), Cornell (1974), and Fagan (1972, 1973, 1977) pointed out, babies of 26-30 weeks should be able to categorize adult female faces. Given that capacity, it may be that the stimulus presentation in Experiment 1 lent itself, because of the changing nature of the faces while emotional expression was held constant during the habituating process, to categorical thinking. One of the reasons that habituation did not occur in Experiment 1 may be that

emotion as a category per se cannot override the novelty effect of the changing faces. Another, somewhat tangential possibility is that the cues for categorization of faces by six-month olds may be independent of expression.

However, the presence of an interaction of the nature described above suggests that, while fragile, there appears to be some asymmetry under certain conditions. This will be elaborated when discussing the results of the second experiment.

The following experiment attempted to expand the findings of Experiment 1 by rearranging the stimulus presentation in the following ways: 1) in the attempt to give the subject greater opportunity to habituate to the stimulus, the habituating stimulus trials were increased from four to six; 2) in order that the task be clear, the habituating stimuli were identical to one another (same face, same expression) rather than being the presentation of the same emotion expressed by different models; 3) the dishabituating stimulus changed along one dimension rather than two such that there were two conditions in which either the face changed or the expression changed. However, there was also a third condition which was similar to the first experiment in that both the face and emotion of the critical stimulus changed, but in the

present context of added trials and non-changing stimuli during habituation. This condition was included in an attempt to maximize the difference between the dishabituating stimulus and the habituating stimulus. It is also possible that the stimulus properties of face and emotion summate or at least have multiple or interactive meaning for the subject. And finally, 4) the expression of surprise was omitted. Happy and sad were used since they seem unambiguously opposite to one another.

1. Subjects

The subjects ($N = 18$) were selected in the same manner as in Experiment 1. Mean age was 6.6 months with a range of 6 to 7 months. However, as in Experiment 1, due to crying and sleepiness, there were missing cells for several of the 18 subjects. Depending upon which elements of the data were compared and analyzed, the subject population changed from 8 to 10 to 18 subjects. This will be discussed further in the results section.

2. Procedure

Testing consisted of two sets of 42 trials each. One set of slides was presented to the right and the other to the left visual field. Each set was arranged in the following way: six sequences of six trials of the same person (male or female) with a sad or happy face followed

by a seventh trial which was one of three possibilities: A) the same person/face with the other emotion; B) a different person/face with the same emotional expression; or C) a different person with a different emotional expression. No model was used more than once so that each sequence was unique with regard to the faces presented.

Given that there are two expressions in this design and three possible dishabituating stimuli, the resultant design is a set of six sequences of seven slides each (see Table 2, page 60). The sequences were arranged in a 4 x 6 Latin squares design and assigned to the subjects in the order in which they were tested (see Table 3, page 61). The order of presentation, LVF or RVF first, was assigned within the Latin squares. But, because of factors out of the experimenter's control (sleepiness and crying), the complete Latin squares were not accomplished. The apparatus and procedure remained the same as in Experiment 1. There was a 5-10 minute time out between the sets of stimulus presentation to the two visual fields in order to allow the infants an apparently much needed interruption of the darkness, monotony and relative immobility.

3. Results

Scoring of the data was done in the same manner as Experiment 1. A random sample consisting of one-third of

Table 2

List of Presentation of Stimuli in Experiment 2

	Condition					
	A	B	C	D	E	F
Habituating Stimulus (sequences 1-6)	Sad	Sad	Sad	Happy	Happy	Happy
Dishabituating Stimulus (sequence 7)						
a) Emotion	Novel	Novel	Same	Novel	Same	Novel
- - - - -	- - -	- - -	- - -	- - -	- - -	- - -
b) Face	Same	Novel	Novel	Same	Novel	Novel
=====	=====	=====	=====	=====	=====	=====

Table 3
Assignment of Subjects in Latin Squares

BABY	SEQUENCE						VISUAL FIELD FIRST
	1	2	3	4	5	6	
1	E	A	F	C	D	B	Right
2	B	D	C	F	A	E	Right
3	C	E	D	A	B	F	Left
4	A	C	B	E	F	D	Right
5	F	B	A	D	E	C	Left
6	D	F	E	B	C	A	Left
7	D	F	E	B	C	A	Right
8	B	D	C	F	A	E	Left
9	A	C	B	E	F	D	Left
10	C	E	D	A	B	F	Right
11	F	B	A	D	E	C	Right
12	E	A	F	C	D	B	Left
13	B	D	C	F	A	E	Right
14	E	A	F	C	D	B	Left
15	C	E	D	A	B	F	Left
16	A	C	B	E	F	D	Right
17	D	F	E	B	C	A	Left
18	F	B	A	D	E	C	Right

both data sets was scored by an independent judge. A concordance of heart rate (plus or minus one beat) of 90% was obtained between judge and experimenter.

a) Descriptive Data

Before reviewing the results across the population, a description of the response patterns of the individual subjects is presented. Figure 2 (page 63) describes temporal change curves for the response to the first of the habituating stimuli in each sequence. Figure 2A shows the mean difference in heart rate for the first stimulus presentation of each sequence (sequences 1 through 6 occurred during first visual field stimulation) and Figure 2B does the same for the first stimulus presentation of the second set of six sequences (sequences 7 through 12 occurred during the second visual field stimulation). This reflects the fact that there was a time break between visual field presentation so that each set of six sequences is treated independently.

Figures 2A and 2B describe a clear temporal change such that by the end of the conditions (sequence 6 and 12), there is a marked reduction in deceleration of heart rate from that in the beginning of presentation to each visual field (sequences 1 and 7). Interestingly, however, at the beginning of testing in the opposite hemiretina (sequence 7), there was a marked recovery of deceleration

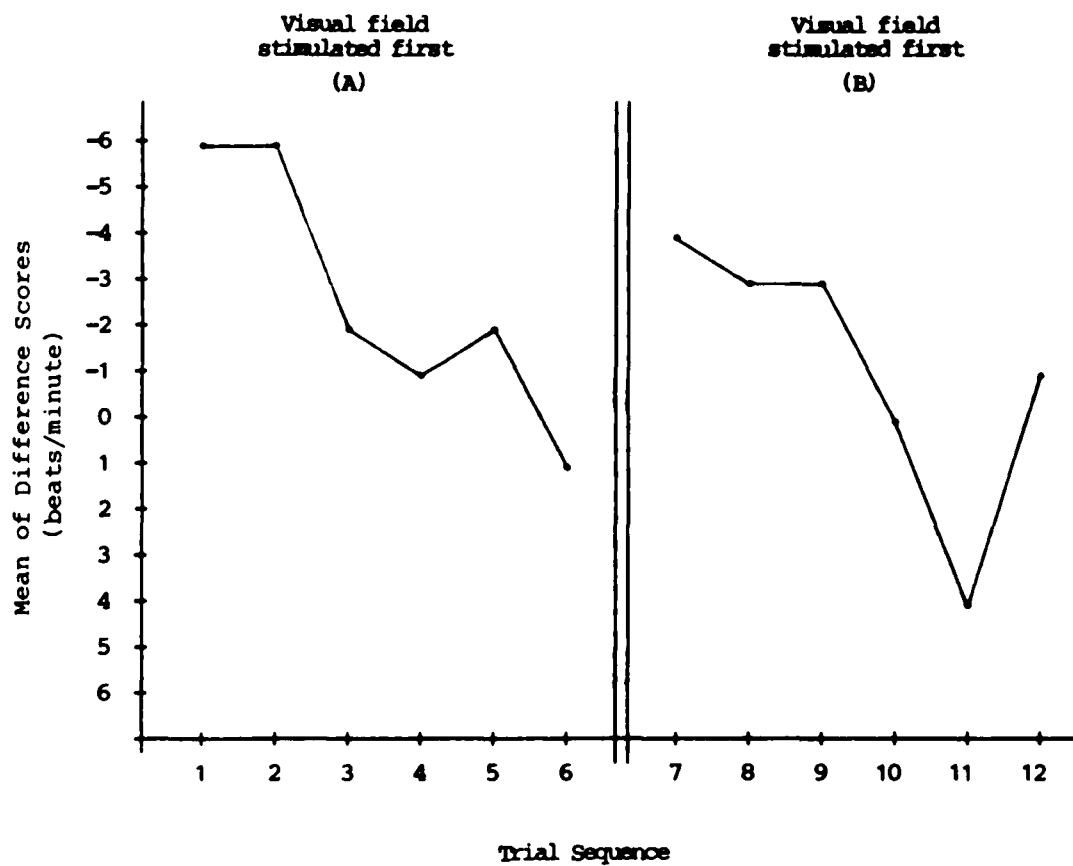


Fig. 2. Change of mean heart rate response (diff. score = H.R. after minus before stimulus presentation) to the first habituating stimulus (trial 1) across sequence of habituation trials in experiment 2. Habituation corresponds to an increasing difference score, i.e., in the downward direction on the Figure.

to the first habituating stimulus. While this may be partly accounted for by the time break between testing of visual fields, it may also be that this increase in orientation demonstrates some degree of hemispheric independence. The changes on the intervening trials in the second half of the experiment may reflect subjects' learning of the process or may be more reflective of fatigue or boredom.

Figures 3A and 3B (page 65) similarly describe change in responding to the set of habituation trials across the twelve sequences in the experiment. The mean values are those of the difference between trials 6 and 1.

As discussed in the introduction, deceleration of heart rate reflects orienting and interest on the part of the subject. Also, depending upon when it occurs during the habituation process, it is an indicator of subject attention and processing of information. Tables 4 and 5 (pages 66 and 67) list the frequencies of subjects whose heart rate decelerates, accelerates, or does not change after each of the first of the habituating stimuli (1) and after the dishabituating stimuli (7). These tables also indicate which frequencies occur at a rate significantly different from chance.

As can be seen in Table 4, the sequences of stimulus presentation in the first visual field stimulated and the

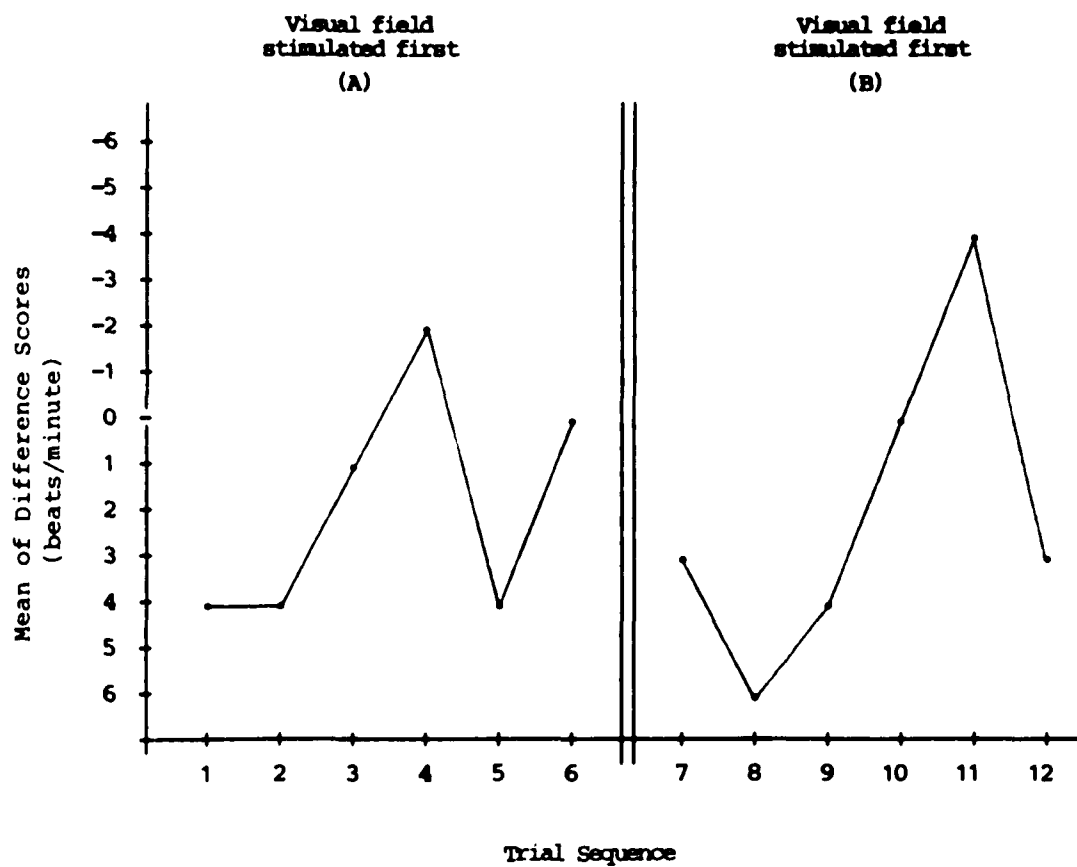


Fig. 3. Change of mean heart rate response (diff. score = H.R. after minus before stimulus presentation) for the difference between the first and the last of the habituating stimuli (trials 1 and 6) in experiment 2

Table 4

Number of Subjects Who Decelerate, Accelerate, or Show No Change
of Heart Rate After First Habituating Stimulus in Each Sequence
of Trials

Trial 1

<u>N=</u>	<u>Sequence</u>	<u>Deceleration</u>	<u>Acceleration</u>	<u>No Change</u>	<u>2-Tailed Sign Test</u>
18	1	14	3	1	*
17	2	12	5	0	
17	3	12	5	0	
15	4	6	6	3	
14	5	7	5	2	
14	6	4	6	4	
18	7	13	4	1	*
18	8	14	3	1	*
18	9	14	3	1	*
18	10	8	6	4	
16	11	5	10	1	
17	12	9	5	3	

* = $p < .05$

Table 5

Number of Subjects Who Decelerate, Accelerate, or Show No Change
of Heart Rate After Dishabituating Stimulus in Each Sequence of
Trials

Trial 7

<u>N=</u>	<u>Sequence</u>	<u>Deceleration</u>	<u>Acceleration</u>	<u>No Change</u>	<u>2-Tailed Sign Test</u>
18	1	16	1	1	*
17	2	8	8	1	
16	3	6	7	3	
16	4	8	6	4	
17	5	9	6	2	
18	6	8	9	1	
15	7	12	3	0	*
17	8	7	7	3	
18	9	9	5	4	
17	10	8	6	3	
16	11	6	9	1	
17	12	9	5	3	

* = $p < .05$

first three sequences of the visual field stimulated second show a significant percent of subjects decelerating after presentation of the first habituating stimulus. The lack of significance in the last sequences of trials suggests that the subjects habituated to the experimental condition itself. Figures 4A and 4B graphically demonstrates this relationship (page 69). These data parallel those of Figures 2A and 2B to some extent, particularly with regard to hemispheric independence.

Table 5 shows that the decrease in deceleration occurs more precipitously after the presentation of the dishabituating stimulus; it is only in sequence 1 that the decelerating response is significantly different from chance, and it immediately thereafter drops to the chance level. The same is true of the first dishabituating stimulus (sequence 7) of the visual field stimulated second. Figures 5A and 5B are the graphic presentation of these data (page 70).

The point to be made here is that a change in responding takes place; the subjects are attending to some aspect of the stimulus; and there is a strong suggestion that each cerebral hemisphere was stimulated independently given the recovery of response at the beginning of stimulation of the second visual field. The fact that the second half of the experiment produces replications of the

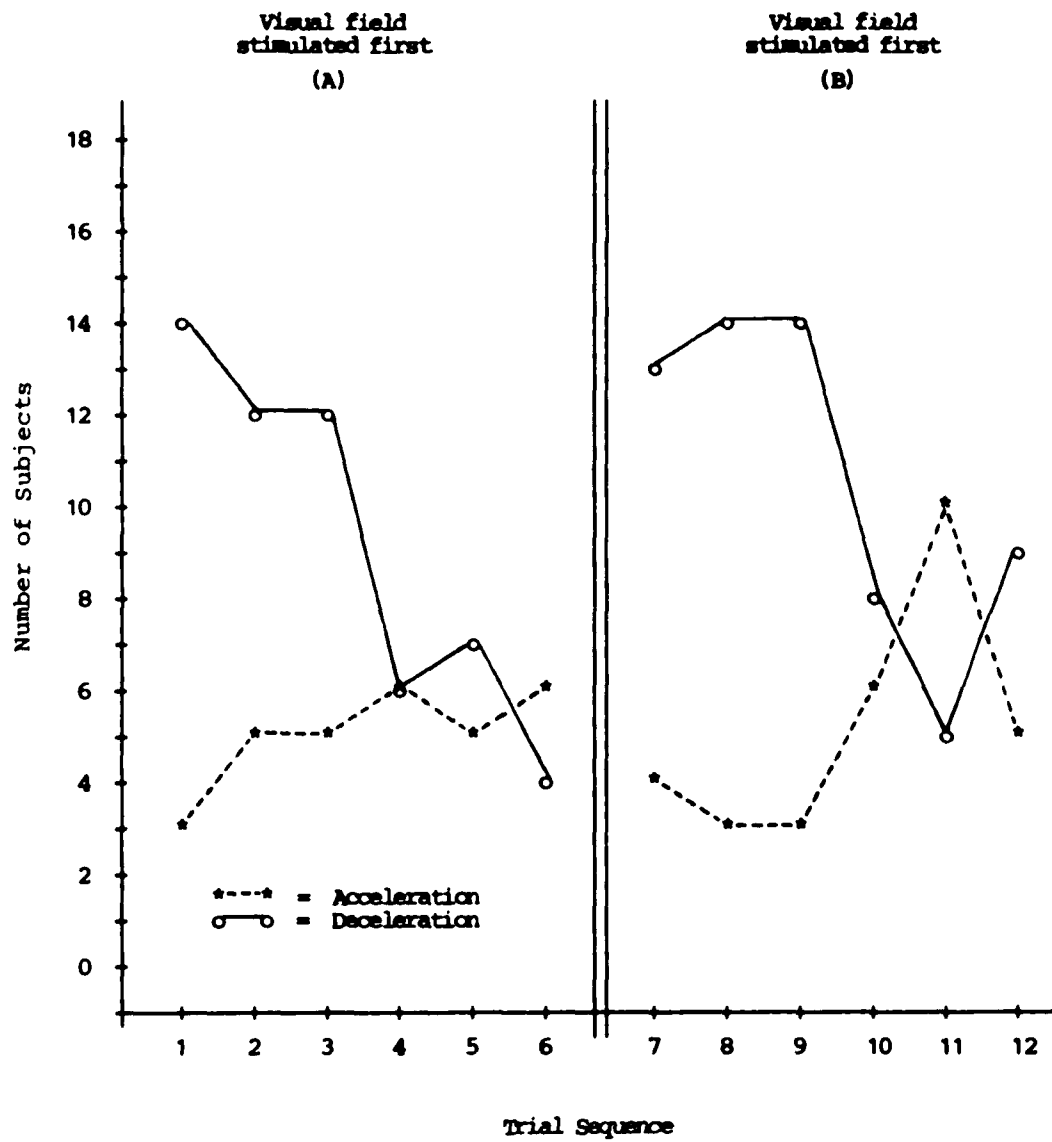


Fig. 4. Change in heart rate after presentation of the first habituating stimulus across ordered sequence of trials in experiment 2

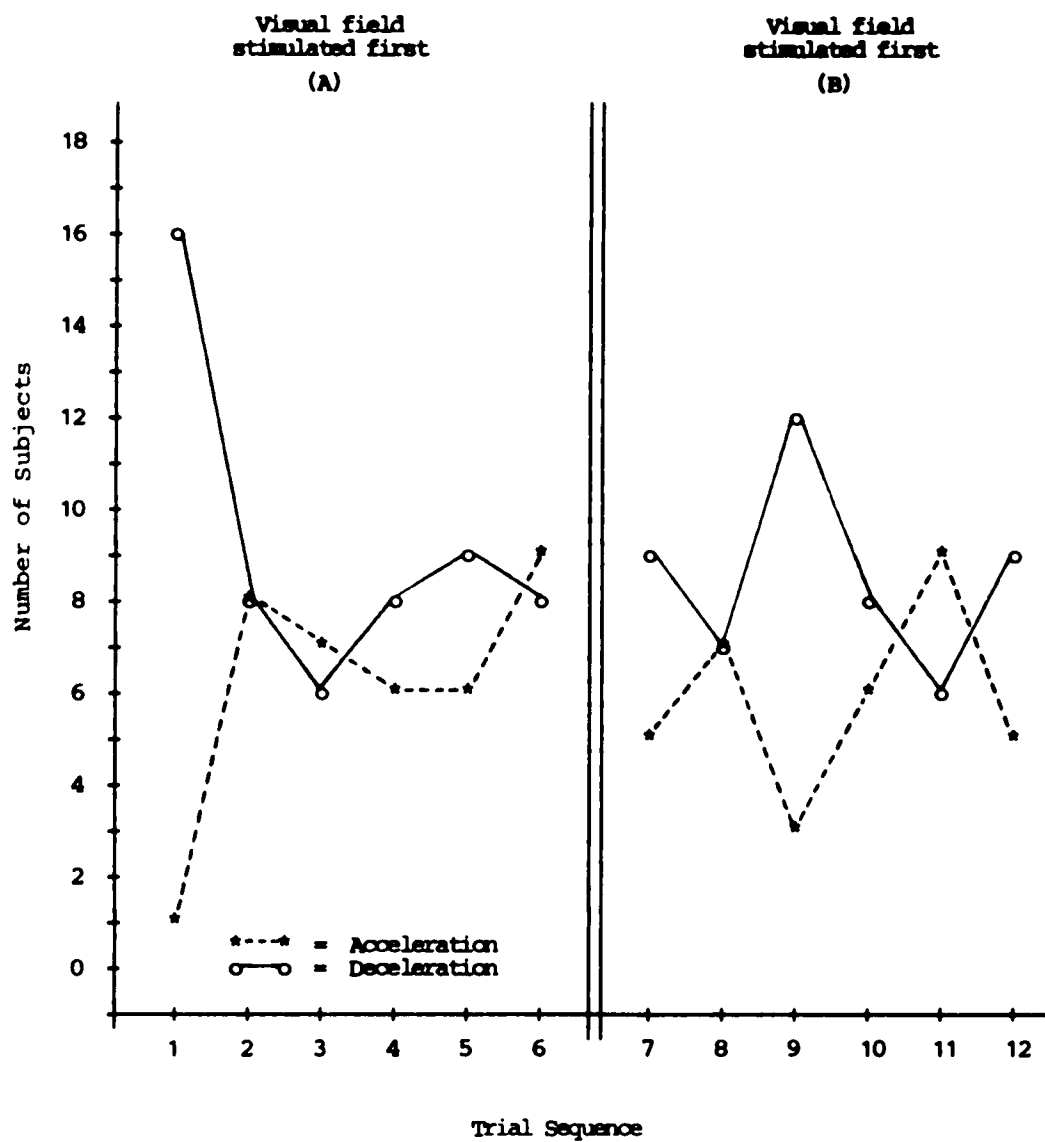


Fig. 5. Change in heart rate after presentation of the dishabituating stimulus (trial 7) across ordered sequence of trials in experiment 2

first more likely indicates a "starting over" rather than continuation of responding.

b) Analyses of Variance (ANOVA)

In an attempt to analyze the data so that habituation, dishabituation, visual field, nature of change and order effects can be described, repeated measures analyses of variance (these are the same measures used and described for Experiment 1) were performed in the following ways: The first data analysis consisted of comparing the first with the last of the habituating trials to assess the process of habituation; and second, the last of the habituating trials with the critical trial (number 7) to determine if dishabituation had occurred.

These analyses were organized in the same two ways as the first experiment. The first vs. sixth trial and sixth vs. seventh trial were compared, as well as the means of the first and second trials vs. the means of the fifth and sixth trials and the means of the fifth and sixth trials vs. the seventh trial.

Each comparison was subjected to a repeated measures analysis of variance with one between-subject (order = 0) and three within subject [visual field (V), trial (T) and sequence (S) (nature of change)] factors. When trials 1 and 6 were compared (habituation phase) there were no significant main effects, but there was a significant

interaction between visual field and order ($N = 8$, $F(1, 6) = 15.21$, $p < .01$; see Fig. 6, page 73). When trials 6 and 7 were compared (dishabituation phase) there were neither significant main effects nor simple interactions. There was, however, a significant second order interaction between visual field, trial, and order ($N = 10$, $F(1, 8) = 7.54$, $p < .03$; see Fig. 7, page 74). There was not, however, a significant interaction between visual field and sequence. This interaction would have provided information about the relationship between the stimulus and hemispheric engagement given that each sequence presented different forms of stimulus change during the critical trial. Proceeding under the assumption that the estimated effect sizes are the effect sizes in the population, the power of the test is small. In fact, the sample size required to produce significance under this assumption is unreasonably large.

The interesting aspect of the interactions found is that they are opposite to one another. Explicitly, during the habituation phase (Fig. 6), when the left visual field is stimulated first there is greater deceleration in response to stimulation of the left visual field than the right. When the right visual field is stimulated first there is greater deceleration during RVF stimulation than the left. However, during the dishabituation phase of the

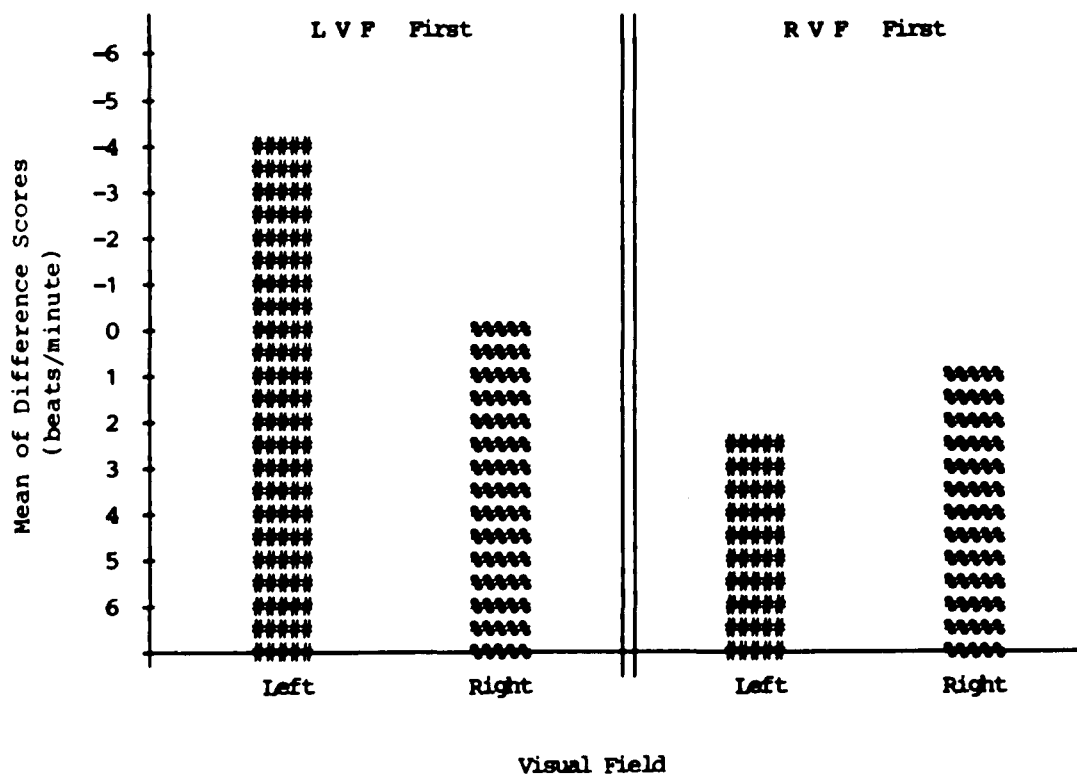


Fig. 6. Visual field x order interaction for first and last of habituating trials (1 and 6) in experiment 2 (unaveraged data)

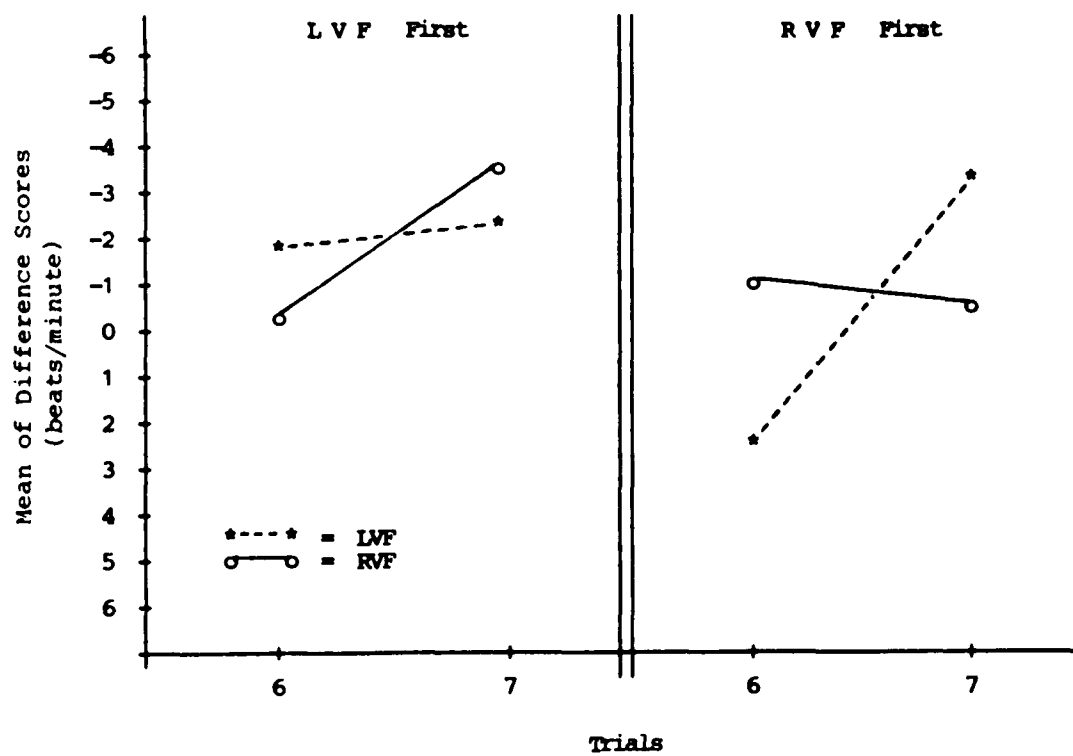


Fig. 7. Visual field x trial x order interaction on trials 6 and 7 in experiment 2 (unaveraged data)

experiment (Fig. 7), the opposite is true. When the left visual field is stimulated first there is greater responding during RVF stimulation. And, vice versa, when stimulation to the RVF is first, then the response is greater during stimulation in the LVF. The interaction in the dishabituation phase parallels that found in Experiment 1 which included both phases of the experiment.

These findings suggest that not only is asymmetry discriminable but also that subjects were responding differently during different phases of the experiment. When different responses were required, different physiological responding occurred.

There was a tendency toward dishabituation which occurred for these same ten subjects ($N = 10$, $F(1, 8) = 4.11$, $p < .08$). There is a possible confounding element in that only the dishabituating stimulus was accompanied by the click of the advancing slide tray. However, since the significant interactions did not include the third condition in which both face and expression changed, it is difficult to conclude that the noise produced cardiac change. [As discussed in the Subjects and Methods section, the sample in these analyses varied because only the subjects who completed all of the sequences (nature of change) for the analyzed trials (e.g., 1 vs. 6) were included.]

The initial sample size was reduced because there were missing data within the sequences. However, since there were neither main nor interaction effects for sequence (nature of change) the data were collapsed across this factor. This allowed the use of the complete subject population by taking the means of the critical trials without regard to completion of a given sequence. By using the means the missing cells were indirectly filled in.

When comparing the average of trials 1 and 2 with that of trials 5 and 6 and then with trial 7 (with sequence factor omitted), a trend toward significance was obtained for the main effect of trial ($N = 18$, $F(2, 32) = 3.02$, $p .06$) suggesting habituation followed by dishabituation. The means indicate a decrease in deceleration of heart rate at the end of the habituation trials and an increase in deceleration of heart rate at trial 7 (trial 1 = -1.5; trial 6 = -.8; trial 7 = -2.1). Also, a Fisher's Least Significant Difference Criterion Test was utilized to determine if there was a significant difference in responding at the beginning (1 and 2) and the end (5 and 6) of presentation of the habituating stimuli. This test was also applied to the differences in responding to the last of the habituating stimuli (5 and 6) and the dishabituating stimulus (7). While there was

no significant difference between the means of trials 1 and 2 and trials 5 and 6, there was a significant difference at less than the .05 level between trials 5 and 6 and trial 7.

These findings strengthen the conclusion that subjects were responding at least to the change in configuration of the stimuli since dishabituation occurred. And, possibly, habituation occurred.

Although there were no main effects for sequence, several ANOVAs were performed post hoc in an attempt to expand our understanding of the differences in responding to the elements embedded in facial recognition. Each sequence was analyzed independently with both the averaged (1 and 2; 5 and 6) and unaveraged data (1 and 6) and the data from the dishabituating stimulus (7).

When the expression was sad and only the face changed, there were no significant main effects nor simple interactions; however there was a significant second order interaction for visual field, trial, and order ($N = 15$, $F(2, 26) = 4.93$ $p .02$) (means: trials 1 and 2 = -1.96, trials 5 and 6 = -.6, trial 7 = -.2) (see Fig. 8, page 78). Once again, the second order interaction suggests the priming effect found in Experiment 1 (Fig. 1) as well as in the dishabituation phase of Experiment 2 (Fig. 7).

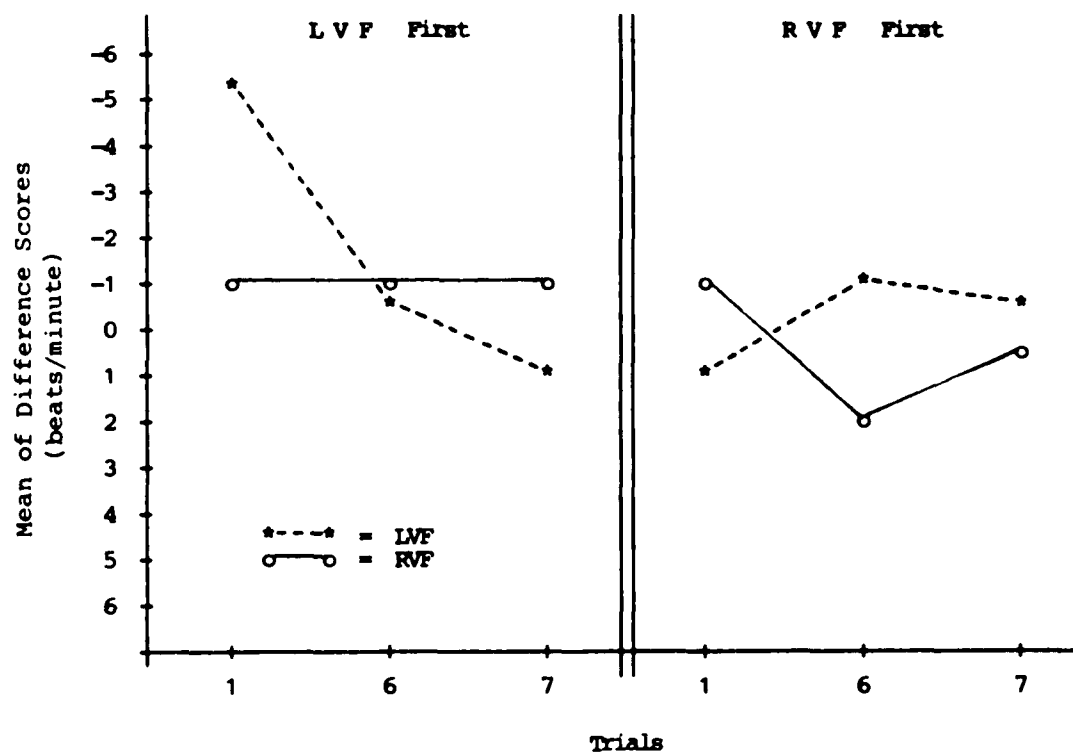


Fig. 8. Visual field x trial x order interaction when face only changes and expression is sad. Averaged data; experiment 2

Analysis of the unaveraged data shows that when expression alone changes from sad to happy there was a significant main effect for trial (6 vs. 7) ($N = 15$, $F(1, 13) = 5.46$, $p .04$; means: trial 6 = 1.4; trial 7 = -2) which indicates that dishabituation took place. When just the face changed (happy expression) there was also a trend toward significance for trial (6 vs. 7) ($N = 14$, $F(1, 12) = 4.54$, $p < .06$; means: trial 6 = -.5; trial 7 = -6) indicating that dishabituation had occurred. However, when both face and expression changed there were no significant findings. These last data are counter-intuitive given our understanding of dishabituation. One possible explanation may be, as suggested above, that changing both aspects of the stimulus creates in some way too much of a change so that the subjects were "thrown off" the habituation/dishabituation track.

While these data are tentative since there was no main effect for nature of change (sequence), they suggest that happy expressions are more salient than sad ones for these subjects.

In summary, the findings of both Experiments 1 and 2 are complex but indicative of change in responding, dishabituation, and lateralization under certain conditions. Experiment 1, with both averaged and un-

averaged data, found an effect such that responding during stimulation to the contralateral visual field produced greater deceleration to the visual field stimulated first. Also, using unaveraged data in Experiment 2, the same configuration was produced when looking at the dishabituation phase of the experiment. However, with unaveraged data, the opposite pattern occurred during the habituation phase of the experiment so that deceleration was greater during stimulation to the ipsilateral visual field to the visual field stimulated first. The point was made that this is a logical outcome given that different processing requirements are intrinsic in the two phases of the habituation/dishabituation process and therefore it is most likely that different hemispheric involvement occurs.

Averaging the data resulted in a main effect for trial in the second experiment. The data show that dishabituation occurred and that subjects responded in a systematic fashion to the stimuli.

Post hoc tests of the various nature-of-change conditions in Experiment 2 also produced a main effect for trial when expression changes and a second order interaction when face changes.

The data are interpreted as indicating that infants can habituate and dishabituate to some degree under these experimental conditions and, given certain conditions of

visual field stimulation, hemispheric asymmetry for the processing of emotion and/or faces is potentiated. In this context it is important to remember that both hemispheres seem to be involved.

DISCUSSION

The early clinical studies (Benton & Van Allen, 1968; DeRenzi, et al., 1968; DeRenzi & Spinnler, 1966; Milner, Taylor, & Sperry, 1968; Warrington & James, 1967) and in particular those performed with commissurotomed patients (Gazzaniga, et al., 1963, 1965; Levy, et al., 1972) point to right hemisphere superiority for recognizing faces. Also, the pathological entity prosopagnosia initially was understood to occur when damage to the right hemisphere was sustained (Bodamer, 1947; Ellis, 1983; Wilbrand, 1892). These findings led to the testing of normals utilizing the tachistoscope. As Ellis (1983) points out, "if research on cerebral asymmetry in processing faces had stopped in the early to mid-1970's we would probably all happily accept that the right hemisphere is better adapted to processing complex patterns, such as faces" (p. 38).

While it has become widely accepted that the right hemisphere has an advantage over the left for processing faces (Geffen, et al., 1971, 1972; Rizzolatti, Umiltà, & Berlucchi, 1971; St. John, 1979) and, to a less clear degree, emotion (Roszkowski & Snelbecker, 1982; Saxby & Bryden, 1984; Suberi & McKeever, 1977), there are enough conflicting data which suggest that this hemispheric advantage cannot be taken for granted (Bertelson, P.,

VanHaelen, H., & Morais, J., 1979; Bradshaw, J.L., Gates, A., & Patterson, K., 1976; Freeman, 1980; Galper & Costa, 1980; Hannay & Rogers, 1979; Hay, 1978; McKeever & Dixon, 1981), at least in tachistoscopic presentation. Phippard (1977) and McReynolds and Jeeves (1978) failed to find right hemisphere advantage in processing faces in children between ages seven and eight (McReynolds & Jeeves) and eleven and fourteen (Phippard). Leehey (1976, unpublished) also reports no left visual field superiority in processing faces in eight-year olds, which suggests that possibly this hemispheric asymmetry is not firmly established by the age of six to eight. However, when using dynamically presented emotional stimuli (videotaped spontaneous production of emotion) rather than static displays, Davidson and Fox (1982) found that ten-month olds demonstrated hemispheric asymmetry in processing specific emotions.

These studies may be understood within one of several theoretical frameworks which grow out of the continuing attempt to assess hemispheric specialization of faces and emotion. The findings of the studies reported herein which indicate no clear asymmetry for this sort of processing in infants can be understood in the same context. It is not enough to assert that since asymmetry was not clearly obtained there is no hemispheric asymmetry

for the processing of faces and/or affect in six- to seven-month olds. What one may assume is that functional asymmetry for this task is not easily demonstrated before a certain age, with perhaps some changes in methodology required even at a later age. It may also be, however, that given neurological development and priorities, this asymmetry does not emerge completely until later and, as will be discussed further, another line of thinking pertains to the complexities of lateralization of this task. The suggestion is also made that clear-cut distinctions between the hemispheres do not exist for facial and emotional recognition tasks in infants.

A. Heart Rate

To begin with, as described in the methods section, heart rate is a recognized indicator of behavioral change. It has a particular pattern such that deceleration of heart rate accompanies orienting responses. In at least one study (Glanville, et al., 1977), it has been used as a method for measuring cerebral asymmetries in infants in the task of auditory perception. In a fixed habituation procedure, Glanville, et al., were able to demonstrate habituation by showing the decline and difference of pre- and post-stimulus beats per minute between the first and last of their habituating trials as well as a recovery of heart rate deceleration on the test trial. Heart rate was

measured for 10 seconds preceding stimulus onset and for 15 seconds following stimulus offset. These results validated the use of heart rate deceleration as a measure of habituation which was then incorporated into their design to assess asymmetry.

The design and results of both of the current experiments, while not exactly those of the Glanville, et al. study, are similar enough to assume confidence in the methodology and its sensitivity to the functions being studied. Given that dishabituation occurred, one notes the subjects attended to the stimuli (faces with emotional expressions) rather than just to stimulation per se. The next question to address is that of the possible parameters of the design which may have an impact upon the form and meaning of the stimulus for the infants and thus hemispheric involvement and interaction.

B. Stimulus Properties and Cerebral Asymmetry

An important development in the study of hemispheric asymmetry in the processing of faces and emotion is the realization that there is no standard measure for assessing this function. Not only is the nature of the stimulus nonuniform (schematic vs. actual; familiar vs. unfamiliar; moving vs. stationary; partial vs. whole configurations; male vs. female; front view vs. profile;

neutral vs. expressive), but the critical variables of intensity, luminance, exposure duration, retinal eccentricity, and stimulus size are also nonuniform throughout the literature (Sergent, 1982, 1983, 1985 unpublished; Sergent & Bindra, 1981).

Another point often overlooked is that these varying stimulus elements ask different things of the brain in its pattern of responding and leave the experimenter uncertain about which of these elements might be the critical ones. This perspective requires that one take seriously the possibility that both hemispheres are involved in the processing of faces and, indirectly, emotional expression. (For an early clinical description of this likelihood see Levy, et al., 1972.) The data from the experiments described in the results section lend validity to the idea that both hemispheres are involved. There are several models of cerebral processing which apply.

Ellis (1983) suggests a complex theoretical model of face processing which relies upon various stages of sub-processing. His contention is that depending upon characteristics of the stimulus and the task, the right or left hemispheres will be involved. The first requirement of processing faces is the classification of the stimulus as a face per se. Ellis offers evidence which suggests this preliminary processing is a property of the right

hemisphere. A related finding is that of Moscovitch, Scullion and Christie (1976) which shows an absence of LVF superiority in the pre-categorical stage of processing and which also suggests stages of processing.

Turkewitz and Ross (1983) were able to demonstrate a complex processing strategy for facial identification which involves subjects shifting from their original visual field advantage to an increase in advantage in the opposite visual field. If the initial advantage was in the RVF, it then shifted to the LVF; if it was originally an LVF advantage, processing shifted to the RVF and then back to the LVF. In addition to the complex processing strategy these data suggest, there is also the obvious reference to the capacity of both hemispheres to process faces, as well as the likely involvement of both. Other authors (Galper & Costa, 1980; Porter & Berlin, 1975; Proudfoot, 1982; Safer, 1984) have offered data which lead to the conclusion that there are most likely levels of processing and strategies employed by the individual which at one time will produce a left visual field advantage and at others a right visual field advantage.

This point of view has implications for the role of memory in the processing of faces. Hay and Ellis (1981) present data which suggest that the right hemisphere is faster at creating mental representations of faces which

can then be "reviewed" when later decisions concerning familiarity are required. But even these data are highly specific and not easily generalizable since they refer only to the task of identity matching rather than detecting facial differences for recognition.

The physical analysis of a stimulus may also involve each hemisphere differentially depending upon the discriminable quality of the stimulus. However, there were no straightforward findings of right hemisphere superiority in these experiments which further complicates our assessment of the salient stimulus properties.

It is considered that the right hemisphere is superior when processing involves impoverished, easily degraded viewing conditions. The theoretical underpinning of this is that the right hemisphere advantage in processing is of an holistic, gestalt nature.

The research reported above is based, to a large degree, on a very specific physical aspect of the stimulus, namely the degree of its visual angle and its displacement on the retina. The angles subtended by the stimuli in this research produce some uncertainty as to what the subjects actually saw and how clearly they saw it.

Conflicting and Negative Findings: Sergeant (unpublished), writing about hemispheric processing of faces, reports that "there are no less than 25 articles published in the last ten years that report data from normal subjects pointing to a specific involvement of the left hemisphere in these processes under some circumstances." In addition to the several studies which Ellis (1983) cites (Bertelson, 1979; Bradshaw, et al., 1976; Hannay & Rogers, 1979; McKeever & Dixon, 1981), Ellis refers to the theses of two of his own students (Hay and Freeman) who were unable to find a left visual field advantage for processing faces.

While somewhat tangential to the purpose of this thesis, the complicated and conflicting evidence of sex differences in cerebral processing of facial and affective stimuli (Hilliard, 1973; Hirschman & Safer, 1982; McKeever & Dixon, 1981; Rizzolatti & Buchtel, 1977; Safer, 1981; Satz, Bakker, Teunissen, Goebel, & Van der Vlugt, 1975; Turkewitz & Ross, 1983) lends support to the developmental complexity of cerebral dominance for this function.

In a summary of studies on cerebral asymmetry for speech in infants, Segalowitz (1977) lists three studies which found no asymmetry for speech (Merryweather, 1978; Molfese, Freeman, & Palermo, 1975; Varga-Khadem & Corballis, 1979). However, he also cites ten which

produced clear evidence of asymmetry. The point this review underscores is that while there is general acceptance of cerebral dominance for both tasks and type of processing, the experiments' data vary and are subject therefore to varying interpretations.

The complex of variables which have been arranged experimentally in a multitude of ways and which have produced conflicting results regarding hemispheric asymmetry in the processing of faces and emotions has relevance for the clinical data in which there is little or no experimental manipulation but rather a correlation between the lesioned hemisphere and the disrupted function (Gainotti, 1972; Goldstein, 1939; Meadows, 1974; Sperry, Zaidel, & Zaidel, 1979). The few studies that attempt to describe the dominance pattern for the processing of emotion have produced inconsistent results which sometimes reflect a left visual field advantage and at other times an equal facility in the right visual field (DeKosky, Heilman, Bowers, & Vallenstein, 1980; Ley & Bryden, 1979; Stambrook & Martin, 1982; Strauss & Moscovitch in Ellis, 1983; Suberi & McKeever, 1977).

C. Anatomical Data

As presented in the introduction, the data derived from empirical, clinical and physiological studies, the substantial body of anatomical evidence which has accumu-

lated has strong implications for the understanding of cerebral asymmetry.

It is a short theoretical leap to correlate the concrete measurable evidence described in the introduction to a wide array of behaviors. The difficulty with applying one level of analysis to another (anatomical to behavioral), however, is that most often the applications are strictly correlational and less clearly causative. Also, the anatomical evidence is based on graded, differential responses and measures while behavior is continuous and hardly, if ever, discrete.

Another possibility to consider is that the processing of these and other similar stimuli does not occur in the cortex at all, but on a subcortical level. There are several collateral pathways which suggest the by-passing or short-circuiting of the cerebral cortex in such a manner so as to produce images which "speak" directly to the autonomic nervous system and, in turn, affect heart rate. For example, the superior colliculus, although more involved in the localization and tracking of objects than in the specific details intrinsic to an object, functions at the subcortical level. There are commissures connecting the right and left superior colliculi so that cortical collosal interruption does not affect the localization of objects. And, significantly

for the findings reported above, the brain stem is believed to spread emotional information between hemispheres as well as the concomitant changes which go along with emotional stimuli.

It is easy to commit a fallacy of linearity and assume that not only is the development of brain and behavior parallel, but linear as well. Therefore, while the anatomic data are compelling evidence of morphological asymmetry, they are inadequate at defining the translation of brain into behavior.

D. Development of Cerebral Asymmetry

There are several competing theories as to how hemispheric specialization and dominance develop. The major proponent of the emergence of specialization is Lenneberg (1967), whose main interest was language development. In that context he proposed a functional asymmetry which emerges gradually throughout childhood and becomes fixed at adolescence. This helped explain findings such as those of Basser (1962) which demonstrated the capacity of young children with left hemispheric lesions to develop language. One interpretation of this data is that of equal potentiality in that functional asymmetry is not yet fixed so that one hemisphere can take over specific functions the other one cannot perform.

Gazzaniga (1970), also concerned with language development, proposed two independently developing language systems which correlate with the partial myelination of the corpus callosum in children younger than two years. His suggestion that there is an interaction between the pressures of right-hand bias and the development of increased neural buildup for language in the left hemisphere is challenged by Witelson (1985b).

Her argument that "this proposition does not account for the early right-hand bias nor the development of left-sided language in the majority of neurologically intact left handers" is indirectly countered by Ramsay's (1980) suggestion of developmental change with regard to handedness. Handedness does not remain stable before approximately 18-24 months but rather alternates between right and left preference in an unpredictable manner. That there are shifts between right- and left-handed biases among babies has relevance for the possibility of changing, unstable, and emerging aspects of lateralization.

Brown and Jaffe (1975) and Hécaen (1976) have also postulated theories of increasing hemispheric specialization for language during the course of human development. However, they have used clinical populations and the certainty of their hypotheses have yet to be validated.

There are other behavioral data which substantiate this theoretical point of view, although not related to language. Those presented above indicate that children under the age of seven do not consistently demonstrate functional cerebral asymmetry, at least with regard to face and affect perception.

However, there are reports of asymmetry in infants, in response to auditory stimuli and these must be accounted for theoretically (Entus, 1977; Glanville, et al., 1977; Molfese, et al., 1975; Segalowitz, et al., 1980). In this context, it is interesting to note that Turkewitz (unpublished) has developed a theory which may help explain why findings of asymmetry in infants are less conflicted for auditory rather than visual presentation of stimuli. His theory also has implications for why lateralization for language in infants is present when lateralization for faces and emotion in infants is questionable.

Essentially, Turkewitz suggests that the prenatal auditory stimulation to which the fetus is sensitive interacts with the different rates of development of the cerebral hemispheres to produce differing degrees of hemispheric asymmetry at birth. He refers to data which show that not only is the prenatal fetus stimulated by and hence accustomed to human language but postnatally is able

to make rather complex discriminations between groups of words or stories. While the theory has several components, what is relevant for the findings in this thesis which suggest that asymmetry for processing of faces and emotion is not fully developed in infants is that it may not be helpful to compare results from auditory/verbal studies with those from visual/face-affect studies.

For example, as discussed in the introduction, Witelson and Barrera (in Best, 1985), using a visual paradigm, demonstrated right hemisphere dominance for the gestalt of mother's face and another complex pattern. At the same time the three-month old infants did not show any visual field preference when looking at a stranger's photo. The authors assert that this parallels adult behavior in that the right hemisphere processes familiar gestalt patterns. Since the female stranger is unfamiliar, they assert that the stimulus is not a gestalt and therefore not processed holistically. To some extent their findings may have more to do with perception of familiar patterns rather than facial recognition.

Mathivet and DeSchonen (1985) report data from experiments with four- to nine-month olds which purport to show that infants in this age range produce cerebral asymmetry for the processing of faces. They state that latencies of the ocular saccade toward mother's face are

shorter than toward a stranger's face and that this effect is stronger in the LVF than the RVF. The critical aspect of their data, however, is that there is significance at greater than .05 for both visual fields, with the p value of the LVF being smaller than the RVF. Without more statistical information it is impossible to evaluate if there is a significant difference between these two values; and, equally important, both p values being less than .05 clearly suggests the involvement of both hemispheres in the processing of faces. Both of these studies suggest a rather complex and unclear hemispheric dominance pattern in infants when asked to process visual presentation of faces.

Yet, that anatomical and functional asymmetries exist at all has led several researchers to argue for a non-emergent, fixed functional capacity for cerebral hemispheric dominance available at birth (Kinsbourne, 1976, Kinsbourne & Hiscock, 1977; Moscovitch, 1977; Segalowitz, et al., 1980; Witelson, personal communication; A. Young, 1983; G. Young, 1977). While neural and functional plasticity are acceptable in this framework, they do not override the more profound cerebral organization of specialized hemispheres which these authors contend is functioning at birth. Differing rates of maturation for each hemisphere is an acceptable possi-

bility within this theoretical context and, as already suggested (Davids, 1969; Valsiner, 1983), at least one author (Witelson, 1985b) considers that it is not hemispheric specialization which changes or develops, but rather cognition. Witelson contends that cognitive development is often misunderstood to represent the development of lateralization.

Another logical theoretical approach to the development of cerebral asymmetry which the findings of the study reported in this project possibly support bridges two points of view; namely, that there is hemispheric asymmetry present at birth, although not immediately apparent, and that it ". . . increases over time due to gradual specialization . . ." (Segalowitz & Chapman, 1980). We might add that this asymmetry is increasingly expressed over time due to other cognitive growth, such as language development.

CONCLUSION

Given the diversity of findings reported at the beginning of this discussion plus the dearth of experimental data from infant studies in the area of hemispheric asymmetry for the perception of emotion, almost any data set can be fit into a consistent acceptable theoretical framework regarding cerebral asymmetry. As yet, it has been impossible to state with certainty that functional asymmetries are completely present at birth, although some appear to be. It is quite likely, as the present studies indicate, that such complex stimulus properties as those which pertain to faces and their emotional expressions are not processed in one hemisphere but, perhaps for infants, in both. The cerebral hemispheres may be separate but equal in this regard in that each hemisphere may process this kind of information equally well.

There are several components to the design of the present studies which are responsive to the embedded issues described above in this field of research having to do with the nature of the stimulus as well as the nature of the response. The question of different response strategies given different types of response requirements is possibly attenuated by the use of heart rate as the dependent variable. The habituation and dishabituation

processes documented in the present studies also allow for repeated presentation of the face. These processes in turn should make the face a familiar stimulus rather than a strange one, and thus address the issue of differences in hemispheric asymmetry depending upon whether the face is familiar or unfamiliar.

While these studies do not produce results such that allow one to be certain about the nature of the stimulus for the infant, it is likely that the subjects are attending to the configurations of form within the stimulus. Otherwise the heart rate should not have changed systematically. It seems probable that, at least at this stage, the infants are not separating face from emotion. They also appear more interested in faces as whole configurations or compounds, rather than in aspects or components of them, such as expression. For six-month olds, faces and emotion seem to be processed both in an analytic and holistic manner therefore implicating the participation of both hemispheres or, ironically, neither. This is borne out by the present research.

However, attention must be paid to the several findings which suggest that hemispheric asymmetry for processing of emotion in infants, if not immediately apparent, may be facilitated by the effects of stimulating first one visual field, then the other.

These data fit nicely with what we know about infant development. It is not linear, fixed, or invulnerable to environmental pressure and change. There is room for flexibility and receptivity to external demands. Order of stimulation in the experiments described is perhaps an example of just such an environmental pressure which interacts with a predisposed internal, in this case cerebral, response set which has not yet fully developed.

Another important aspect of this study is that it is one of the first two successful examples of the use of split-screen tachistoscopic presentation to assess asymmetry in the visual mode in infants. The findings of these studies will hopefully be heuristic and lead to further research which can possibly answer the question of when, if there is hemispheric dominance for processing faces and affect, this dominance becomes clearly discriminable? And, of course, how does this dominance develop and with which other developmental strides does it possibly interact? Another important question is what role does the integration and transfer of information between hemispheres play in this form of processing? And, is emotion an integral part of the processing of faces, or is it nonessential information; can emotion be processed qua emotion without the context of a face?

Further research would profit by the use of more familiar stimuli such as the mother's face among the testing variables, as well as perhaps habituation to criterion rather than fixed habituation trials. Also, longitudinal studies should give a more complete picture of individual development of the brain and its relationship to the development of other cognitive and behavioral capacities.

Another important consideration has to do with the manner of presenting the emotional expression. In a recent paper, Caron, Caron, and Myers (1985) found that infants of 17-29 weeks habituated to nonspecific features of the stimuli ("presence or absence of bared teeth") rather than those features the authors expected to be information giving about affect. While the photographs in the present experiments had both "toothy" and "nontoothy" expressions, there may have been additional nonspecific cues to which the subjects responded and which interfered with the perception of affect. Caron et al. suggested that infants in this age group may have difficulty altogether in "extracting emotional information from static stimuli." Therefore, future work would perhaps benefit from the use of more dynamically relevant information such as that to be found in live or taped displays of emotion.

It is hoped that this research will be the first of many studies attempting to address these important questions and issues.

Finally, a review of the present findings is both provocative and leading. They challenge the idea that cerebral asymmetry is simple and straightforward. They raise the possibility of a model of interaction rather than competition between or independence of hemispheres. Order of hemispheric stimulation and degree and kind of responding within hemispheres has relevance for overall findings of lateralization. And these findings, being so different from the more usual data obtained with adults, support the position that asymmetry is a developmental attribute of cerebral function.

APPENDICES



THE MOUNT SINAI MEDICAL CENTER

ONE GUSTAVE L. LEVY PLACE • NEW YORK, N.Y. 10029

Mount Sinai School of Medicine • The Mount Sinai Hospital



Dear Ms. _____:

You will be called within the next two weeks to see if you are interested in having your child participate in a research study being conducted at Mount Sinai Hospital. This project has been approved by the institutional review board and is being run by a graduate student from The City University of New York under the aegis of a full-time academic member of the Department of Pediatrics.

The project has been designed to provide data about how the brain processes information about emotion. Your child will be shown slides of human faces and his/her visual reaction will be observed as well as heart rate. The entire session will take no longer than 30 minutes.

There are no immediate benefits to having your child participate in this research. The information obtained, however, may aid in future detection of neurologic problems that some children experience in early life.

Any questions you may have will be happily answered by the observer. Participation is voluntary and may be discontinued without penalty. Individual identity of participants will remain confidential.

Thank you in advance for your cooperation.

Sincerely,

Barbara Stimmel
Research Coordinator

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LISTING OF RESEARCH PROJECTS
 NEWCASTLE AND DISTRICT
 1900-1909

1900-1909

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LISTING OF DATABASE FOR PROJECT 433
 (1) ANALYSIS AS OF 2/24/60
 (2) RESULTS USED FOR

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