CEREBRAL ASYMMETRY OF EMOTION AND ITS RELATIONSHIP TO OLFACTION IN INFANCY

by

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Abstract

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Because of the close relationship between emotional parts of the brain and olfaction and since infants respond to smells Sarnat, 1978: Lipsitt, Engen & Kaye, 1963), olfaction can be a tool in assessing emotional development and laterality. Taking advantage of the olfactory ipsilateral connections (right nostril projects to the right hemisphere etc...) smells differing in affective valence (predetermined by adults) were presented to 42 neonates via a specially designed apparatus. Each infant was presented with 2 positive and 2 negative food-related odorants. An air stream was utilized as a neutral stimulus. In all cases the 4 odorants were paired with the neutral stimulus. Each pair was presented two times, once with the odorant being delivered to the right nostril and once with the odorant being delivered to the left nostril. These 8 trials were repeated in 4 blocks producing a total of 32 trials. In addition, control trials, where a puff of air was administered to both nostrils, were included.

The presentation of the odorants was completely counterbalanced. In an attempt to discern any lateralized differentiated responding, reactions to the odorants were videotaped while the infants slept. The frequency of hand movements, head movements and sucking behaviors was noted. Results revealed that on each dependent measure (head, hand and sucking), infants responded significantly more to the smells than to the control. An additional finding was that sucking occurred more frequently when the smells went to the left hemisphere as opposed to the right.

Study 2 tested a number of hypotheses regarding emotional lateralization. Head movements served as the the dependent measure. At each trial's start, the newborn's head was held in a midline position and directionality of initial head turns was noted. A significant interaction with Smell x Nostril x Direction was found. Post hoc analyses revealed significant effects occurred only for the positive smells. When the positive smells were presented to the left hemisphere, neonates made significantly more head turns toward the smell. This raises the possibility that approach behaviors may develop earlier than withdrawal behaviors.

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INTRODUCTION

That the two cerebral hemispheres of the adult assume asymmetrical functions in terms of language and a variety of other functions has been established in the literature. There are indications that aspects of emotional behavior are among these lateralized functions however the precise nature of any such lateralization is still a subject for considerable debate. The present dissertation was designed in an attempt to reduce the number of alternative possibilities concerning the nature of hemispheric specialization with regard to emotion. Numerous hypotheses regarding emotional lateralization have been proposed and will be reviewed. One major theory states that emotions are a function of the right hemisphere - Right Hemisphere Hypothesis (Borod & Koff, 1984). An alternative postulate, the Valence Hypothesis, advocates differential hemispheric involvement in emotional experience with the right frontal hemisphere specializing in negative affect, while the left frontal hemisphere dominates in positive affect (Fox & Davidson, 1982). The great majority of studies on laterality of emotion have been conducted on adults. The current investigation focused on aspects of emotional lateralization in newborn infants. Because of the close relationship between emotional areas of the brain and olfaction and the fact that infants respond to smells

(Sarnat, 1978), olfaction may provide a tool to examine emotional development, and laterality. For example, the Right Hemisphere Hypothesis would be supported if both positive and negative smells evoke a greater response when presented to the right hemisphere than when presented to the left hemisphere. On the other hand, the Valence Hypothesis (described below) would be supported if negative smells produce more of a response when presented to the right hemisphere than when presented to the left hemisphere, and positive smells produce more of a response when presented to the left hemisphere than when presented to the right hemisphere.

This review focuses on the following concerns: 1) hemispheric asymmetry in infancy, 2) relationship of emotion to hemispheric differentiation 3) the relationship of olfaction to emotion.

1) Hemispheric Asymmetry in Infancy

The ontogeny of cerebral lateralization has been examined by investigating the asymmetry present in fetal brains. Neuroanatomical (Galaburda, LeMay, Kemper & Geschwind, 1978) evidence has accumulated which suggests that cerebral lateralization is present at birth. It has been noted (Galaburda & Habib, 1987) that, as early as the middle of gestation in the human fetus, anatomical asymmetries have been detected. Pyramidal decussation asymmetry has been shown in newborn and fetal human brains (Yakovlev & Lecours, 1967). LeMay (1977) points out that CT scans of neonates reveal a similar pattern to the adult in that the anterior end of the right hemisphere and the posterior end of the left hemisphere are often wider and protrude farther than their counterparts.

In terms of the hypotheses concerning emotions and laterality when considering the development of asymmetries, focus should not only be on right/left (inter) hemispheric differences, but also on the anterior/posterior (intra) hemispheric time course. Not only do the hemispheres develop at different times but, within each hemisphere itself, a time gradient exists.

Normal brain development proceeds in an anterior-to-posterior manner, thus, the anterior regions develop prior to the posterior ones (Best, 1988). However, researchers do not agree as to which hemisphere (right or left) develops first. Corballis & Morgan (1978), Goldman (1972) Liederman (1983), and Yakovlev & Lecours (1967) believe that the left hemisphere matures first. Supporting this, infants have been observed to reach out for objects of interest more with their right hands (using left hemisphere) than with their left (Young, Segalowitz, Misek, Alp & Boulet, 1983). Ultrasound observations reveal that fetuses from 15 weeks to term have a marked bias for sucking the right hand (Hepper, Shahidullah

& White, 1991). In addition, infants have been observed to lie more often with their heads turned to the right than to the left (Turkewitz, Gordon & Birch, 1967).

In contrast, Best (1988), Brown and Jaffee (1975), Galaburda et al.(1978), Taylor (1969), Tucker (1981), and Whitaker (1978), believe that right hemisphere development precedes that of the left. Studies supporting the claim that the right hemisphere develops earlier, as well as faster, come primarily from anatomical and seizure studies.

Anatomically, it has been noted (Chi, Dooling, & Gilles, 1977) that the superior temporal region, as well as some cerebral convolutions appear earlier, by as much as 2 weeks (Galaburda, 1984), in the right than the homologous left-sided region.

Taylor (1969) reports that seizures which are more likely in immature than mature brain tissue are more common in the left than right hemisphere suggesting a maturational lag in left hemisphere development. Having a more prolonged period of growth, these slower developing structures are less vulnerable to early disruptive influences and thus, ultimately, reach a greater size and complexity of organization. This follows the more general principle that slower developing brain structures ultimately become larger and more complex. For a much more extensive review on this issue see Geschwind and Galaburda (1987), and Turkewitz

(1988).

An alternative postulate regarding the time sequencing of the hemispheres is that it is not an either/or situation ie., either the right develops first or the left, but rather which hemisphere develops more quickly differs by area within the hemispheres.

Ontogeny of Emotions

A debate exists in the literature as to, not only what constitutes an emotion, but also when specific emotions emerge.

Definition of Emotion. Examining the first issue, theorists disagree over the precise definition of an emotion. The term "emotion" has been used to refer to a class of elicitors, states, behaviors, and experiences. Emotional states are inferred constructs which are defined in terms of alterations in somatic and/or neurophysiological activity (Lewis & Haviland, 1993). These states can occur without the organism's conscious awareness. The issue, as to whether cognition plays a role in the development of emotional states, is debatable. The manifestations of internal emotional states are known as emotional expressions which are defined by changes in the face, voice, body, and activity level (Ekman & Friesen, 1974).

Emotional experience, on the other hand, involves the interpretation and evaluation by individuals of their perceived emotional state and expression. Emotional experience demands its perceiver to attend to his/her emotional state.

Emergence of Specific Emotions. Until recently, researchers believed that neonates exhibited only an undifferentiated emotion and that discrete emotions slowly emerged as the result of maturation and experience. It was proposed that voluntary smiling does not usually occur until the infant is 4 to 6 weeks (Sroufe & Waters, 1976), surprise can be elicited by 5 months (Charlesworth, 1964), anger at 7 months (Stenberg, Campos & Emde, 1983), with fear and sadness emerging during the last quarter of the first year (Bowlby, 1972). Thus, it has been suggested by emotion theorists (Ekman, 1972; Izard, 1971) that the primary emotions, happiness, sadness, anger, disgust, surprise, fear, distress/pain, and interest appear over the first year of life. These emotions are all associated with unique facial patterns which have been found to be relatively consistent across diverse cultures.

The view that infants only exhibit an undifferentiated emotion has been rendered obsolete. It has now been observed that directly after birth newborns exhibit interest by staring intently at objects, disgust in response to foul tastes, distress at being restrained and a precursor to surprise- startle in response to sudden noise (Izard, 1977; Izard, 1978). Campos and Barrett (1984) suggest that all of the above primary emotions are present in the newborn and are dependent on a prewired innate process. What changes over time are the expressive capacities and emotional elicitors.

The discrepancy among researchers, in terms of the time course in which a particular emotion emerges, may be the result of confounding the first expression of an emotion with the first experience of an emotion. It is important to distinguish what aspects of emotion are being investigated: interpretation, perception (comprehension), experience, expression (production) or identification (recognition). Each of these dimensions may be differently controlled.

Interpretation involves the perception, discrimination, and memory of emotional stimuli. Perception involves the receptive processing of the emotional aspects of a stimulus according to Borod, Andelman, Obler, Tweedy and Welkowitz (1992). Experience involves subjective feelings and, according to Hatfield, Cacioppo and Rapson (1993), is shaped by facial, vocal, and postural mimicry and expression. The emotional experience subjects feel tends to be affected by the facial expressions they adopt. Finally, emotional expression is manifest by differences in muscular action in the face and body, posture and movement, modulation in voice and breathing patterns, and in language (Zajonc, Murphy & McIntosh, 1994). Odom and Lemond (1972) claim that the three processing modes: perception, expression and experience, not only develop at different times but, also can be independent of one another (Borod, 1993a).

Experience and Expression. Some studies, Gainotti, (1987) and Heilman, Watson & Bowers (1983), Ross and Rush (1981), demonstrated that affective experience and expression can be dissociated. For example, pseudobulbar palsy, affecting the brainstem, can produce behaviors such as laughing or crying bouts without the appropriate affect being experienced.

Perception and Expression. Perception is not considered a prerequisite for expression (see Izard's 1977 studies with blind infants to further support this). Similarly, data from studies (Borod, Koff, Lorch & Nicholas, 1985) with brain damaged subjects show that perception and expression can also be dissociated. Ross and Rush (1981) described 10 right-hemispheric lesioned subjects who exhibited dissociation between expressive and perceptual behaviors. Interestingly, their pathology was dependent upon the localization of the lesion: anterior or posterior. When the lesion was localized to the anterior lobes, emotional expression (production) seemed to suffer, whereas, with a posterior lesion, perceptual (comprehension) deficits were noted (Borod et al., 1985).

2) Relationship of Emotion to Hemispheric Specialization

Challenges have been proposed to the long-standing hypothesis that the right hemisphere specializes in processing of affect in general. Currently, a number of hypotheses have been proposed; three of these, with their modifications, will be outlined: the Right-Hemisphere Hypothesis, the Valence Hypothesis, and the Approach/Withdrawal Hypothesis. Following this, studies will be presented as evidence for the various hypotheses. The issue of hemispheric specialization for emotions remains unresolved; with divergent camps existing, the debate continues.

1)The Right-Hemisphere Hypothesis

Many researchers contend that the right hemisphere is dominant for all emotions, regardless of channel (perception, expression or experience). This is known as the Right-

Hemisphere Hypothesis (Borod, Kent, Koff, Martin & Alpert 1988).

1a) Modification I of The Right-Hemisphere Hypothesis

A slight modification of the Right-Hemisphere Hypothesis proposes that the valence of the emotional experience is dependent upon the level of right hemispheric activation. Thus, negative emotional experiences are associated with an overactivation of the right hemisphere; while positive experiences are associated with an underactivation of the right hemisphere (see Levy, Heller, Banish & Burton, 1983).

1b) Modification II of The Right Hemisphere Hypothesis

This modification emphasizes that the right hemisphere is specialized for the expression of facial emotion Borod & Koff, 1990).

2)The Valence Hypothesis

The Valence Hypothesis advocates differential hemispheric involvement of emotions regardless of processing mode (expression, perception or experience). The right hemisphere is said to specialize in negative emotions, while the left specializes in positive emotions (Lee, Loring, Dahl, & Meador, 1993).

2a) Modification I of The Valence Hypothesis

A slight modification of the Valence Hypothesis contends that differential specialization occurs for expression as well as experience, but that in terms of perception, the right hemisphere is dominant (regardless of valence) (Bryden 1986, Davidson 1985; Ehrlichman, 1987; Hirschman & Safer, 1982; Silberman & Weingartner, 1986)

2b) Modification II of The Valence Hypothesis

Davidson (1984) adds an additional stipulation to the Valence Hypothesis, stating that the differential specialization that occurs for expression and experience, only does so for the frontal regions, whereas right hemispheric domination occurs only for the posterior regions.

2c) Modification III of The Valence Hypothesis

Another variation suggests that the negative affect is associated with the right hemisphere while positive affect is associated with both hemispheres, bilateral involvement (Best, Womer & Queen, 1994; Borod, Koff, & White, 1983).

2d) Modification IV of the Valence Hypothesis

Tucker and Frederick (1989) advocate a reversed form of the Valence Hypothesis with the right hemisphere specializing in positive emotions and the left specializing in negative emotions.

3) The Approach / Withdrawal Hypothesis

Schneirla (1957) noted the ubiquity across phylogeny of approach/ withdrawal behaviors. It has been proposed that the origin of emotional hemispheric asymmetry is based upon the distinction between approach and withdrawal. A number of researchers (Davidson, 1984; Davidson & Tomarken, 1989; Davidson, Ekman, Saron, Senulis, & Friesen, 1990; Fox, 1991; Kinsbourne, 1988) have suggested that the left hemisphere is intimately tied with approach behaviors and the right hemisphere is tied to withdrawal.

3a) Modification of The Approach/Withdrawal Hypothesis

A modification to The Approach/Withdrawal Hypothesis proposes that it might not be the emotions per say that are lateralized but, the motor programming. Kinsbourne (1978) argues that the frontal asymmetry found in some of the studies represents motor specialization, with the left hemisphere better suited for approach behaviors, while the right is better suited for withdrawal behaviors.

Overlapping Predictions-

Clearly an overlap exists between The Valence Hypothesis and The Approach/Withdrawal Hypothesis. As stated earlier the pure Valence Hypothesis advocates right hemispheric specialization for negative affects and left hemispheric specialization for positive emotions. But, what are "negative" and "positive" affects? They have never been clearly defined. The terms usually are used synonymously with 'pleasant' (wherein you approach something) and 'unpleasant' (wherein you withdraw or flee from something).

Ekman (1972) states that there are seven basic emotions which are universally recognized and elicit distinct facial responses independent of culture. These emotions are happiness, sadness, anger, fear, disgust, surprise, and contempt. Of these, happiness elicits the only unambiguous positive affect and disgust the only negative one. There appears to be ambiguity among the negative emotions (sadness, fear, contempt, and anger) in that not all negative emotions are associated with withdrawal.

Sadness and contempt may not solely elicit withdrawal; for instance, sadness appears to involve a blend of responses. It is speculated that sadness involves both approach, and withdrawal elements. "In the absence of weeping or distress a sad facial expression may reflect the individual's attempt to both regain the lost object of attachment while withdrawing from the event that triggered this loss. Therefore, one might expect relative left frontal activation to the extent that the approach system is elicited" (Fox & Davidson, 1984, p.374). In support of this, Bowlby (1972), describes infant's emotional reaction to separation as an initial attempt to regain the caretaker's presence thus, an approach response.

In contrast, Davidson (1985) claims that disgust, fear, and contempt are the three negative emotions most likely associated with right frontal activation because of their association with withdrawal.

In terms of anger, the problem, up to now, has been one of categorization. Is anger to be considered a negative emotion (lateralized to the right), an approach behavior (lateralized to the left) or, a withdrawal behavior (lateralized to the right)? The studies looking at anger have found that it is not a "pure" emotion, rather a blend having positive and negative components. Anger is lateralized to the left hemisphere when it is expressed in the absence of crying and to the right when accompanied by crying (Fox & Davidson, 1988).

Likewise, surprise is difficult to classify; it can either be pleasant or unpleasant. Therefore, when conducting studies on emotional laterality it is important to delineate which negative emotions are associated with right hemispheric activation. Until researchers agree as to what they mean by "negative" and "positive" and which emotions are pure or have mixed components of both, the literature on emotional laterality will continue to be confusing.

Early in infancy, approach (interest) and withdrawal (fear and disgust) appear to be activated, one at a time, with little interhemispheric transfer between the two (Fox & Davidson, 1984). However, over time and with development, various emotional elements can be coordinated into complex affective responses. This idea is particularly attractive since it correlates well with the idea that right hemisphere overactivation (possibly due to damage to the left frontal region) may lead to a form of depression characterized by signs of withdrawal, psychomotor retardation, and apathy (Davidson & Cacioppo, 1992). In fact, Davidson (cited in Lewis & Haviland, 1993) contends that "activation in the left anterior region is associated with approach-related emotions; deficient activation in this region is associated with emotion-related phenomena that might be best described as reflecting approach-related deficits, such as depression; and activation in the right anterior region is associated with withdrawal-related emotions such as fear and disgust and withdrawal-related psychopathology such as anxiety" (p. 145).

The Evidence -

Clearly, emotional lateralization has been well documented by a sufficiently large number of studies to warrant closer inspection. The findings are based upon clinical neurological studies, psychiatric patients, and studies on normal adults, employing both behavioral, as well as, electrophysiological data (Tucker, 1981). It is beyond the scope of this paper to present evidence from clinical populations as excellent reviews exist (see Borod, 1993b). Instead, studies on normal subjects will be examined.

Over the last three decades neuropsychological studies on hemisphericity, the relative importance of one hemisphere, have been conducted on normal subjects using behavioral and physiological indices. Among the most widely used methods to study laterality are: tachistoscopic visual-field studies, lateral eye movements, lateral orientation studies, dichotic auditory tasks, and EEG recordings.

In terms of emotional perception, tachistoscopic viewing, as well as dichotic presentations have been used. First, it is important to remember that a left advantage in tachistoscopic viewing and dichotic studies implies right hemisphere processing since both these types of studies are designed to present stimuli in a manner producing initial contralateral excitation.

Visual-Field Studies. Visual field studies with normal neurologically intact subjects typically employ tachistoscopic stimulation to a specific field, right or left, which projects to the contralateral hemisphere. Presentation times are approximately 150 milliseconds or less to ensure that the information is initially exposed to one hemisphere (Young, 1981). Numerous researchers employing lateral tachistoscopic studies with human faces have found differences in emotional reactivity. Independently, two groups of researchers, Reuter-Lorenz & Davidson (1981) and Suberi & McKeever (1977), assessed hemispheric asymmetries as measured by reaction time in the perception of sad and happy faces. The researchers reported that reaction time was faster and more accurate when the expression of sad was presented to the left visual field. Likewise, the reaction time was faster when the right visual field was presented with the expressions of happy and also angry. Additionally, Dimond, Farrington, and Johnston (1976) reported that when a film was presented via a special contact lens to the left visual field (right hemisphere), it was rated more negatively than when it was presented to the right visual field (left hemisphere). The right hemisphere also judged pleasant and unpleasant films as more horrific; yet, no significant differences were found for judging the films as more pleasant.

In an extension of the above study, Dimond and Farrington (1977) added another variable to their study: heart rate. Supporting the Valence Hypothesis, they reported a faster heart rate when an unpleasant film was presented to the right hemisphere than when the same film was presented to the left hemisphere. A faster heart rate was detected when a humorous film was presented to the left hemisphere compared to the right hemisphere. Additionally, (Davidson, Mednick, Moss, Saron & Schaffer, 1987) reported subjects' experiencing happier feelings when information was initially presented to their left hemisphere as compared to the presentation of the identical information to the right hemisphere. These studies were replicated by Reuter-Lorenz, Givis, and Moscovitch (1983) but not confirmed by Duda and Brown (1984).

Graves, Landis & Goodglass (1981) reported hemispheric differences in the recognition of emotional words (mostly negative) which were more accurately reported when presented to the left visual field (right hemisphere) of males. However, for females, no significant hemispheric difference was found.

Examining the pattern of asymmetry in the interaction of perceptual and expressive aspects of facial emotion Mandal and Singh (1990) found that negative emotions were identified more accurately when presented to the right hemisphere. The above visual field studies suggest "...that either the right hemisphere generally interprets the world more negatively than the left hemisphere, or the right is more sensitive to the negative aspects of the world than the left" (Otto, Yeo, & Dougher, 1987, p.1204).

A criticism of studies employing facial stimuli in emotional perception is the confounding of two processes, recognition of faces and perception of emotional expressions. Psychophysical studies of face perception using the technique of visual half field presentation have indicated that faces are best perceived in the right hemisphere (Donnelly & Riddoch, 1993; Humphreys, McLaren & Bryson, 1987). Thus, hemispheric differences in face recognition may mask or masquerade as hemispheric differences in the perception of facial expressions. To dissociate the two, Hugdahl, Iversen, Ness & Flaten (1989) introduced a collection of highly schematic faces, confirming that information regarding emotional expression is processed independently of facial identity. However, in their attempts to avoid confounds they may have inadvertently produced others. Schematic faces consist of simple geometrical stimuli which are processed better in the right hemisphere, potentially biasing their results.

Lateral Eye Movements. An alternative method for studying cerebral specialization has been described by Kinsbourne (1972). Lateral eye movements, (LEM's), refer to shifts in eye gaze, to the right or left, that occur when people engage in reflective thinking (Ehrlichman & Weinberger, 1978). The theory, known as hemispheric asymmetry model of LEM's, posits that the direction, in which eyes and head move, is an indication of activation of the contralateral cerebral hemisphere, particularly the frontal lobes. In addition, a significant component of eye movement control resides in the frontal cortex (Robinson & Fuchs, 1969) which has been implicated in the regulation of affective behavior (Pribram, 1973). Gur et al. (1980) have validated the use of lateral eye movements as indices of hemispheric activation. These investigators have correlated LEM's to regional cerebral blood flow, demonstrating a direct relationship. Consistent with this finding, lateral eye movements have also been linked to electroencephalographic recordings (Bakan & Svorad, 1969).

In support of the Right Hemisphere Hypothesis, Schwartz, Davidson, and Maer (1975) reported LLEM's responses to emotional as well as neutral questions. Adding emotional valence, Ahern and Schwartz (1979) provided support for the Valence Hypothesis reporting differences in lateral eye movement asymmetries as a function of experimentally induced mood. When normal subjects were asked emotionally upsetting negative questions, LLEM's were found to be more pronounced. Positive questions of happiness and excitement elicited a greater number of RLEM's (see also Borod, Vingiano, & Cytryn, 1988, for studies which contradict this). However, the use of lateral eye movements has not been without critics.

A criticism regarding the use of lateral eye movements is one of confounding the intensity of the stimuli with the stimuli themselves. For example, in the Ahern and Schwartz study (1979), the emotional questions may have been confounded with intensity in that the subjects rated the positive emotional questions as less intense than the negative ones. The more extreme or intense emotions are better recognized, by adults when they are presented to the right hemisphere (Ley & Bryden, 1979; Suberi & McKeever, 1977).

This type of confounding is not only a problem for lateral eye movements, but is also an issue in judging emotional faces.

Facial Asymmetry. Facial expressions of emotion have been the focus of many studies in the neuropsychological literature (for review see Borod and Koff, 1984). Many factors are involved in facial asymmetry: whether the emotional expressions were posed (voluntary) or spontaneously generated, from what area of the face (upper or lower) is the emotion judged, the emotional valence (positive or negative) of the expression, and, finally, the sex of the subjects expressing the emotion, as well as, judging it (see discussion below on sex differences).

In order to assess emotional expression, subjects are told to produce an expression upon a verbal command (posed) or are caught, a la candid camera, spontaneously producing an expression. Raters are then asked to judge the two sides of the face for asymmetry. Normal, right-handed adults report the left side of the face, or hemiface, as expressing emotions more intensely than the right hemiface, thus implicating the right hemisphere (Borod & Caron, 1980; Campbell, 1982; Heller & Levy, 1981; Rubin & Rubin, 1980; Sackeim & Gur, 1978). Studies have differed in their agreement as to whether it matters if an expression is posed or not. Some researchers (Damasio & Maurer, 1978; & Geschwind, 1975) claim that the two ways of expressing emotions may be mediated by different, independent neuroanatomical pathways. According to a study conducted by Borod & Koff (1990), it did not seem to matter whether the emotion was posed or spontaneously produced (see review by Borod, Koff, & White, 1983).

Since cortical innervation patterns are different for the upper as opposed to the lower part of the face, this must be examined further. Facial expressive muscles can be divided into two major areas: the upper part of the face (temporofacial) and the lower part (cervicofacial division). The temporofacial area includes the muscles around the eyelids, eyebrows, and the forehead. The cervicofacial area includes the muscles around the mouth, chin, and lower cheeks (Rinn, 1984). Cortical input to the cervicofacial area is contralateral, whereas the input to the temporofacial division is bilateral, arising from both cerebral hemispheres (Best & Queen, 1989).

Taking the above factors into consideration, Borod, Koff and White (1983) studied patterns of facial asymmetry as a function of elicitation condition (posed or spontaneous), emotional valence (positive and negative expressions), and sex of subjects. Findings corresponded with past studies reporting expressions to be significantly left-sided. In addition, when introducing sex and valence, for all subjects, differences were found with negative expressions being left-sided; while for males only, positive expressions were also left-sided. For females, positive expressions were significantly less lateralized than negative ones (for an additional discussion on this see latter section on sex differences).

Lateral Orientation Studies. Lateral orientation studies have corroborated the findings of the lateral eye movement studies. Dawson, Tucker & Swenson (1984) reported that subjects who exhibited more right body movements (contralaterally innervated) tended to describe themselves more favorably. Further support is provided by Drake and Bingham (1985) who demonstrated that when a subject's head is turned to the right he/she evaluated him/herself more optimistically and tended to view pictures more positively. In contrast, when the head is turned to the left, subjects tended to evaluate others more favorably. Thus, the affective state in which an individual enters certain situations depends, to some extent, on which hemisphere is more in control of the behavior at that time.

Dichotic-Listening Studies. Dichotic listening is another commonly used noninvasive neuropsychological technique for assessing cerebral dominance. The original dichotic listening studies were conducted by Kimura to investigate the nature of lateral perception of auditory stimuli. Kimura observed that normal adult subjects were more accurate in identifying verbal material presented to their right ear than the left ear under conditions of dichotic presentation (cited in Murray, Allard & Bryden, 1988). The theory, usually referred to as the direct-access model, states that impulses from material presented simultaneously to each ear ascends exclusively to the more dominant, contralateral pathways in the brain, suppressing input carried by the weaker, ipsilateral ones. It is, therefore, possible to take advantage of the nervous system's arrangement and present stimuli to each hemisphere separately.

Reviewing laterality research in terms of emotions, Bryden and Ley (1983) found that emotional stimuli, regardless of valence, are perceived more accurately when presented to the left ear or right hemisphere. Further supporting the Right Hemisphere Hypothesis, Blumstein and Cooper (1974) and Haggard and Parkinson (1971) reported a LEA (left ear advantage) when identifying sentences differing in emotional intonation. Carmon and Nachshon (1973) reported a significant LEA in matching sounds (laughing, crying, shrieking) to its corresponding facial counterpart.

Again, the question, as to whether studies confound the lateralization of emotions with the lateralization of the stimuli themselves, must be entertained. Since speech is lateralized to the left (in the majority of right-handed subjects), the "words" themselves could cause a lateralization to the left hemisphere. Researchers (Borod et al.,1992; Ley & Bryden, 1981; Safer & Levinthal, 1977), attempting to tease apart the two, showed a LEA for recognizing emotional intonation (happy, sad, or angry) of spoken sentences, with a REA for recognizing the verbal content of these same spoken sentences. The results of these studies have indicated a right-hemispheric superiority in judging the emotional tone of an auditory stimulus.

EEG Studies. An alternative procedure, used to examine asymmetries of hemispheric activation during the generation of emotions, is to take electroencephalographic recordings while presenting affective stimuli. In reviewing EEG studies, it became evident that the results reported depended upon exactly where the recording site was (frontal, temporal or parietal lobe). The following issues must be considered when using EEG's. First, specification must be made in terms of what rhythms are being recorded: alpha, or theta. Reduced alpha power, known also as alpha blocking or desynchronization, corresponds to an activation of the underlying cortex and tends to occur during behavioral arousal or active involvement with a task. Theta rhythms are related to the emotional limbic center of the brain. Secondly, the effects of varying the intensity of the emotion should be assessed. And, finally, the task demands must be noted (see Safer and Leventhal, 1977).

Denisova (1978) recorded EEG patterns from children who were engaged in a positive emotional activity and noted theta rhythm was expressed better in the right frontal hemisphere.

Recording from the frontal and parietal lobes, Davidson, Schwartz, Saron, Bennett & Goleman, 1979; Davidson, Schaffer, & Saron, 1985 showed subjects television programs that varied in terms of affective content. Significantly greater left-frontal alpha activation was noted during the most positive episodes; however, when recording from the parietal lobes no difference was noted between positive or negative conditions.

Testing normal female right-handed adults, Ahern and Schwartz (1985) also found differential lateralization for positive and negative emotions in the frontal lobes with relative left-hemispheric activation (as measured by decreases in alpha amplitude) for the positive emotions and relative right-hemispheric activation for the negative emotions. When recordings were taken from the parietal zone, a right-hemispheric specialization for emotions regardless of affective valence was found.

Harman and Ray (1977) took EEG recordings of the temporal lobe while they asked their subjects to remember positive and negative events. Their findings revealed that the positive emotions elicited more right hemispheric activity, indicating less brain activity, while the negative emotions elicited greater left hemispheric activity. These results are diametrically opposed to Davidson's (et al., 1979 and 1985) study. To reconcile the conflicting results, Campbell (1982), in a review on the lateralization of emotions, proposes that this may be the result of one or all of the following. Different sites of recording may have been used (Harman and Ray placed electrodes more rostrally than Davidson et al., 1979 study); the emotions may have been experienced with varying degrees of intensities; finally, the studies may have differed in terms of requiring the subjects to use language or imagistic processes (Harman and Ray's subjects were asked to talk about their emotional experiences).

Gender-related differences further complicate the literature on the lateralization of emotions.

Sex differences and handedness. Numerous discussions on differences of functional hemispheric specialization have focused upon sex differences and handedness. A number of researchers (Borod & Koff, 1984; Strauss & Moscovitch, 1981) contend that females are more lateralized in terms of emotional processing. Ladavas, Umilta, and Ricci-Bitti (1980) demonstrated a LVF (right hemisphere) superiority for females, but not males, in recognizing emotional expression which is consistent with findings from Ley and Bryden (1979) and Suberi and McKeever (1977). However, not all researchers investigating emotional asymmetry have observed sex differences (Bryden, 1982; Landis, Assal & Perret, 1979;

Safer & Levinthal, 1977; Vrana, 1993).

Most studies find that women are more facially expressive than men (Buck, Savin, Miller & Caul, 1972; Schwartz, Ahern & Brown, 1979). In addition, Borod and Caron (1980) found a sex difference in facedness, with females being more lateralized (left-faced) for emotionally pleasant and communicative expressions, while men were more lateralized for negative and reactive expressions.

Evidence has also accumulated that handedness may affect, or be related to, different patterns of left and right hemispheric maturation. Emotional asymmetry effects appear to be the most clear cut for right-handed subjects. "These observations combined would tend to group maleness and left handedness on one extreme and femaleness and right handedness on the other, with left handed men and right handed women being most distant vis a vis asymmetry" (Galaburda, Rosen, & Sherman, 1990, p.538; see also Heller & Levy's, 1981 study on the difference between right and left handers).

The Contradictions

Contradictory reports abundant in the literature, in terms of the relationship of emotions to hemispheric differentiation, may be the result of confounding the following: components of emotion being addressed, i/e, expression, perception or experience; how emotions are elicited, i.e, spontaneous or voluntary (Borod & Koff, 1984; Ekman, Hagar & Friesen, 1981; Kowner, 1995; Rinn, 1984; Schiff & MacDonald, 1990); stimuli responsible for eliciting emotions, i.e, visual/facial, auditory, etc., (Schiff & Lamon, 1989); whether stimuli are already lateralized (Borod, St. Claire, Koff, & Alpert, 1990; Hugdahl, Iversen & Jonsen,1993; Suberi & McKeever, 1977); how emotions are assessed: self-reported, physiological or behavioral indices (Lang, 1984; Vrana, 1993); and finally, subjects themselves (Tucker, 1981), i.e, normal, abnormal, females, males, adults, children, infants, right-handed or left-handed. All of these factors must be clearly specified when engaging in research on emotions.

Since the majority of brain research on asymmetry has been conducted on adult samples, there exists a paucity of data on infants. To fill this void, a number of investigators have begun to address this issue. Since infants' emotions are spontaneously produced, studies with this age group may help illuminate some of the unresolved controversies found in the adult literature.

Infant Studies

Fox and Davidson (1982) have demonstrated, in 10-month old female infants, differential hemispheric asymmetry similar to that seen in adults, with left-sided frontal hemispheric activation (recorded via EEG) in response to videotaped presentations of happy facial expressions and right-sided frontal activation during sad expressions; but, no difference was noted in the parietal lobes. In an attempt to extend these findings to an even earlier age, Fox and Davidson, (1986) conducted a study on newborns, 2 to 3 day olds, recording EEG patterns from the frontal, as well as parietal lobes, while presenting positive (sucrose) and negative (citric acid) tastes. The findings indicated that the newborns, unlike the 10 month olds, responded with right frontal, as well as, right parietal activation to the negative taste and left frontal and left parietal activation to the positive taste. To explain these divergent findings, in terms of frontal and parietal activation, Chugani and Phelps (1986) suggest that the newborn brain may not have developed the functional specificity found in the older babies.

Infants' Facial Responses

Investigating infants (2, 4 and 6 months) Matias and Cohn (1993) found that, compared to boys, girls consistently showed more positive facial expressions.

According to Differential Emotions Theory, DET, (Ekman, 1984; Izard & Malatesta, 1987), emotional expression during infancy is a reliable index of discrete emotions in infants. These discrete emotions are said to have innately determined neural substrates, characteristic neuromuscular expressive patterns, distinct subjective qualities and are stereotypical in nature. However, according to Camras (1992) infant facial expressions alone may not reflect the presence of discrete feeling states.

In addition, infants' facial asymmetries are particularly interesting to study since these expressions are undoubtedly spontaneous, not yet influenced by either social conditioning or cultural display rules, as opposed to voluntary expressions. Deliberate emotional posing, as well as, the ability to mask an emotion is thought to develop sometime during the second year of life, presumably with the maturation of the frontal lobes (Oster & Ekman, 1978; Rothbart & Posner, 1985; Sroufe, 1979).

3) Development of Olfaction and its Relationship to Emotions

Until recently, chemoreception's role in the development of affect has been a neglected topic of research. "The emergence of affective representations appropriate to particular stimuli is undoubtedly an important point of early development. Things come to be known as pleasant or unpleasant, and the chemical senses are involved in the earliest of these affective distinctions." (Crook, 1978, p.258). In fact, a whole new field of study- Aromacology, the study of odors and their effect on behaviors- has begun in earnest. Our sense of smell can be extraordinarily precise, yet it is almost impossible to describe to someone how something smells. This is why smell has been called the mute sense. The physiological link between smells and the language centers is weak, but the connections to the memory centers, (especially the amygdala), compensate for this. Although the names of smells are forgotten feelings are remembered.

Physiology of Olfactory System

Broca in 1878 emphasized the strong relationship that the limbic system shared with the olfactory apparatus. Since then, research (Kandel & Schwartz, 1985) has shown that olfactory information has relatively direct access to brain structures governing emotions - the limbic system. As a consequence of this, the limbic lobe has been called the rhinencephalon- the smell brain. The outline of the olfactory pathway has been known for over two decades. An odor, which is a mixture of molecules floating in the air, enters the nose and travels to the top of the nasal passages where it comes in contact with very specific olfactory receptors located in the olfactory epithelium (which lies at the top of the nasal cavity). In some cases, the odorant comes in contact with free nerve endings from the ophthalmic and maxillary divisions of the trigeminal nerve also located within the nasal epithelium (Doty, 1990). In addition, some of the chemicals inhaled are detected by nerve endings within the oral cavity and pharynx. Cranial nerve I receptors mediate qualitative odor sensations, whereas the other nerves mediate sensations such as: warmth/coolness, irritation and sharpness (Doty, Kimmelman, Lesser, 1986).

The axons of the olfactory receptor neurons become enwrapped by Schwann cells and form the olfactory nerves, which will project to the olfactory bulb (at the base of the brain). After the first synapse in the olfactory bulbs, secondary neurons (mitral and tufted cells) pass ipsilaterally via the lateral olfactory tract to form a second synapse in the anterior olfactory nucleus. Tertiary neurons project to the pyriform cortex (lying at the anterior end of the hippocampal gyrus) where two main projection routes have been identified (Keverne, & de la Riva, 1982). One route is to the thalamus (medialis dorsalis) which subsequently projects to the neocortical cognitive areas (specifically the orbitofrontal cortex). In addition, the orbitofrontal cortex receives direct input via the olfactory tract. The orbitofrontal cortex also receives an indirect projection from temporal areas via the medial dorsal nucleus of the thalamus

(Krettek & Price, 1977; Nauta, 1972). It has been proposed by Nauta (1972) that the orbitofrontal cortex may be important for olfactory discrimination.

The alternative pathway is to the preoptic/lateral hypothalamic region, the noncognitive limbic system. At this point, numerous ascending and descending projections link the incoming neurons with every part of the limbic system. Of particular importance are the extensions which project to the corticomedial nucleus of the amygdala. The brain structures implicated in computing the affective valence of a stimuli are the various nuclei in the amygdala (LeDoux, 1987). The amygdala, in contrast to the hippocampus (the seat of memories), matures early and is functional at birth.

This limbic pathway is thought to mediate the affective component of odors. The limbic system, specifically the amygdala and the hippocampus, project to multiple regions controlling endocrine, autonomic, as well as, motor activity. Thus, It has been proposed (Engen, 1982) that olfaction may encompass endocrine effects with far-reaching behavioral effects. From the amygdala, there exists a pathway back to the frontal lobes. Researchers (Flor-Henry, 1987; Gruzelier & Venables, 1974; Kolb & Miller, 1981) have reported that the frontal lobes are more likely to be involved in affective disturbances than are the posterior lobes. The frontal lobes may exert an inhibitory influence on cognitive, motor, as well as, behavioral processes. In fact, frontal lobe damage results in what is called disinhibition syndrome.

Ipsilateral Connectivity of the Olfactory Pathways. It is important to stress the fact that the olfactory pathways that project to the limbic system are ipsilateral; what enters the right nostril projects to the right hemisphere and vice versa (Koelga, 1979). Contralateral pathways do exist, via the corpus callosum and the anterior commissure but, these routes are slow to develop.

The cerebral commissures, which are the largest fiber system in the brain, are among the slowest to develop. In fact, Yakovlev and Lecours (1967) have stated that myelination of these fibers, which increases electrical impulse conduction, is not complete until at least 13 years of age. The corpus callosum, though present at birth, appears disproportionately smaller when compared to that of adults. Likewise, at birth, the anterior commissure has not reached full maturation (Witelson, 1989). Since the commissural pathways of an infant are less developed, there exists less interhemispheric transfer of information, resulting in a relative independence of functioning. Lacking efficient interhemispheric communication, the infant behaves more or less like a split brain subject.

Taking advantage of this ipsilateral olfactory pathway, Teitelbaum (1972) cut the anterior commissure in rats and found that it abolished the inter-nostril transfer of olfactory discriminations. Similarly, Kucharski and Hall (1987, & 1988) tested newborn rats with an olfactory learning task. The experiment involved plugging one naris while simultaneously stimulating the remaining naris with a milk odor. It was discovered that, with rats younger than 12 days of age, the memory for a learned odor was confined to the same side of the brain as the stimulated naris and learning did not transfer to the other naris. However, with the 12 day old rats, olfactory learning could be recalled by stimulating either the trained or untrained naris. Thus, it was seen that the commissural systems subserving bilateral olfactory communication (the anterior commissure) did not mature until the second week of postnatal life. When the anterior commissures were cut prior to training, unilateral learning resulted. The importance of the anterior commissure for interhemispheric transfer is not limited to rats. Sectioning of this commissure in homing pigeons destroys their ability to transfer inter-nostril olfactory information used for orientation (Foa, Bagnoli & Giongo, 1986).

The idea that olfactory perception could be lateralized in humans was demonstrated by Gordon and Sperry (1968) who surgically severed the corpus callosum and other forebrain commissures of patients to alleviate their severe epileptic seizures. They found that odors were recognized only in the hemisphere ipsilateral to the stimulated nostril.

Background Studies Supporting the Link between Olfaction and Emotions

Initial investigations indicate that odors can elicit changes in mood (Baron, 1980; Baron, 1990; Ehrlichman & Bastone, 1992; Van Toller, 1991). It has been reported (Berkowitz, 1983, 1990) that foul odors can elicit aggression, as well, as anger. In contrast, when positive odorants were surreptitiously placed in an interview room, job applicants were evaluated more favorably (Baron, 1990).

In a relatively recent study (Halpern & Ehrlichman, 1988) it was found that the number of happy memories elicited by neutral words varied as a function of whether subjects were exposed to mildly pleasant or unpleasant odors during recall.

Development of Olfaction

"...Little is known about the development of olfactory function as well as the function of olfaction during development" (Alberts, 1981, p.322). This is surprising since it has been reported that the sense of smell plays at least some role in man's safety, digestion, reproductive physiology, recollections and emotional life. "Functionally, smell may be to emotion what sight or hearing is to cognition..." (Engen, 1982, p. 3). When an odor is involved, feelings are elicited before cognitions (see LeDoux, 1989 for anatomical evidence to support this). Olfaction is the sleeping beauty of the senses; the time has come to awaken it.

Information regarding the ontogenetic status of olfactory structures and which components of nasal chemoreceptors are functionally active in utero is beginning to be uncovered. There exist three, nasal chemosensitive structures in humans: the primary olfactory receptors, the trigeminal nerve endings, and the nervus terminalis, whose function still is unknown (Keverne, Murphy, Silver, Wysocki, & Meredith, 1986; Tucker, 1963). A brief understanding of the two main chemosensitive contributions is, therefore, necessitated.

Primary Olfactory Receptors. The primary olfactory receptors are said to differentiate early in embryonic development (Schaal, 1988). In fact, as early as the 8th-10th gestational week, the primary olfactory bulbs can be seen and, approximately a week later, the receptor cells appear.

At about the 9th-11th week, the ciliated neuroreceptors are thought to be capable of normal olfactory performance. The olfactory neuroepithelium may also be structurally mature enough prior to birth to be capable of sensory activity. This hypothesis gains support when considering the following findings. Premature newborns (28 weeks' gestation) have responded differentially to the presentation of a peppermint extract odorant as opposed to a control trial in which no odorant was presented (Sarnat, 1978). Additionally, at about the 28th postovulatory week and not before, olfactory marker protein has been traced to the epithelial layer of the olfactory system (Margolis et al., 1985).

After 4-6 months, the epithelial plugs lining the external nares which, until this time have blocked the passage of amniotic fluid, have disappeared. Using 2-deoxyglucose, it has been shown that the olfactory pathways are functional in utero (Pedersen & Blass, 1982). Also in utero there are adequate olfactory stimuli contributed by both the fetus and the mother's chemical ecology. The composition of the amniotic milieu, previously thought to be odorless, is, in fact, quite the opposite. Both fetus and mother contribute to the composition of this fluid. Fetal waste products which are constantly being transferred, greatly effect the amniotic environment (Abramovich, 1981). In addition, molecules ingested (aromas of the diet) or inhaled by the mother (perfumes, cigarette smoke), and stress related factors may induce changes in the amniotic chemistry of a sufficient amplitude to overcome adaptation of the fetal nasal chemoreceptors (Schaal et al., 1985). Other chemicals found in the amniotic fluid include glucose, fructose, lactic, pyruvic, citric acid, fatty acids, phospholipids, creatinine, uric acid, urea, proteins, salts, amino acids, and polypeptides (Mistretta & Bradley, 1977).

It has been demonstrated (Bradley & Mistretta, 1975) that mammalian embryos (humans) actually ingest the amniotic fluid at the 12th gestational week. Taste receptors are also present and functional at the 12th week (Mistretta & Bradley, 1977). It is important, at this time, to briefly mention the significance of taste to olfaction.

Taste (gustation) refers to the sensation that occurs when chemicals stimulate taste receptors on the tongue. Actually, what we think of as flavor is a combination of taste and smell. There exist two passageways whereby an odor can reach the olfactory receptors: the nasal(orthonasal) and retronasal. Odors can enter the nostril during inhalation (orthonasal route) or they can travel from the back of the nasopharynx (which connects the back of the mouth to the nose) toward the roof to the nasal cavity (retronasal) during suckling in infants.

Hauser, Chitayat, & Berns (1985) observed that, when mothers ingested spicy foods prior to delivery, their newborn's body odor was tainted with spicy odors as well. This makes sense since it has been shown that, as pregnancy progresses, the placental barrier becomes increasingly permeable to any maternal influence (Kerpel-Fronius, 1978). In rats, embryonic exposure to olfactory stimuli has been shown to establish a preference post-natally for the same olfactory stimuli (Pedersen & Blass, 1982).

Instead of introducing the olfactory stimuli into the amnion, Hepper (1987, 1988) simply fed pregnant rats one clove of garlic a day from gestation day 15 to day 21. The rationale, behind this indirect technique to exposing embryos to chemical stimulation, is that embryo's olfactory receptors respond electrophysiologically to olfactory-related stimuli which are injected into the bloodstream (Maruniak, Silver & Moulton, 1983). The results of the study indicated that offspring of mothers who had been fed garlic during pregnancy exhibited a preference for the garlic odor (no food was ever actually ingested) as evidenced by spending more time near the dish of garlic, as opposed to a dish of onions.

To help resolve the issue as to whether the preference for the garlic was established prenatally as opposed to a postnatal preference as a consequence of the ingestion of the "garlic-tainted" milk, Hepper performed a second experiment (1988). This experiment was identical to his first study, except that the rat pups were fostered to a non-garlic fed mother within an hour after birth (though critics comment that this study would have been stronger had the offspring been delivered via cesarean, then immediately fostered eliminating the hour of brief nursing). The findings demonstrated a garlic preference in the offspring.

Trigeminal System. The trigeminal nerve, which innervates the nasal cavity becomes differentiated between the 7th and 10th post-ovulatory weeks. The receptors of the trigeminal system are the free nerve endings of the posterior nasal, nasopalatine, and anterior ethmoidal branches of the opthalamic and maxillary divisions of the trigeminal nerve (Keverne et al., 1986). The nasal cavity is innervated by parts of the ethmoid and nasopalatine branches. The exact projection of the chemosensory inputs is not known; however, it has been suggested that it may follow the ascending somatosensory pathways and proceed contralaterally to the thalamus and parietal cortex. In contrast to the olfactory system, direct projections to the limbic forebrain have not been detected.

Traditionally, the trigeminal chemoreceptors have been seen as responsible for triggering a protective withdrawal reflex, (physiological effects include: apnea, bronchodilation or bronchoconstriction, bradycardia, reduction in cardiac output, vasoconstriction, an increase in epinephrine secretion and variable effects on blood pressure), that occurs in response to irritating, noxious chemical vapors (Silver & Maruniak, 1981). Evidence has been provided (Silver & Moulton, 1983) that the trigeminal system may also respond to non-irritating chemicals and, likewise, that the olfactory system may respond to noxious stimuli (Stone & Robert, 1970). "Purely" trigeminal sensations (if there are such things) include pungency, tickle, cool, warmth, burn, sting, pain, and, in addition, trigeminal stimulation may contribute to the overall perceived intensity of an odorant (Cain & Murphy, 1980). It is important to distinguish between stimulation mediated by the olfactory nerve, first cranial nerve, and the trigeminal nerve, fifth cranial nerve, which involves experiences of pain and irritation and not olfaction in the physiological sense. The strength of the odor, or its intensity, may determine the extent to which the different nerves are stimulated (Cain, 1974). Odorants possess a trigeminal component; yet, the degree to which the trigeminal is stimulated is concentration dependent, with little trigeminal impact at low concentrations.

Next, the following response measures: detection, localization, and discrimination of olfactory and trigeminal stimuli will be explored.

Response Measures

1) Detection

Evidence suggests that infants are capable of and respond to smells with sucking, increased facial responsiveness, and body movements, as well as, disturbed respiratory activity within the first several days after birth (Engen, Lipsitt & Kaye, 1963; Rovee, 1969, Sarnat, 1978; Self, Horowitz & Paden, 1972; Schaal, 1988).

Sarnat (1978) tested normally-developing infants, whose gestation period was greater than 32 weeks, and found that they exhibited what he termed an "arousal-withdrawal" response, (increased sucking, flaring of the nostrils, brief eye opening, head or arm movement), when presented with a peppermint extract (trigeminal stimulant). In contrast, infants of less than 32 weeks exhibited reduced responsiveness.

2) Discrimination

In one of the earliest controlled studies, Engen, Lipsitt and Kaye (1963) tested 20 asleep infants' (approximately 50 hours old) reactions to odorants (acetic acid, phenyl ethyl, anise oil, and asafetida) presented via Q-tips. The responses that were recorded included respiration, leg withdrawal, and general movement. The findings revealed that infants discriminated among the smells with olfactory sensitivity increasing over the first few days of life. Reduced responsiveness was noted as a function of repeated exposure to the same odorant, with behavioral recovery following a prolonged interval between odor presentations (thus, the infants habituated).

3) Localization of smells

Rieser, Yonas and Wikner (1976) studying twenty, 1-5 day-olds, presented an offensive odor of ammonia (trigeminal stimulant) below their right or left nostril. They found that the newborns consistently responded to the odorant by turning away from it. In fact, in 64% of the trials, the infant turned away from the odor, whereas they turned towards it in only 30% of the trials. In addition, it was found that when the infants did not turn away from the odor, they tended to turn towards the right. This finding of a right-turning bias in the newborn is consistent with the work conducted by Turkewitz et al. (1967).

Sex Differences

Women are more sensitive, in general, to odorants than men (Koelega & Koster, 1974). They are better at discriminating, identifying, and detecting odors than men (Cain, 1980; Doty, Applebaum, Zusho, & Settle, 1985; Doty, 1992). In fact, Wallace (1977) found that women can discriminate between a male and female on the basis of olfactory cues from the hand. Mothers, but not fathers, are said to recognize the odor of their newborn child (Porter, Cernoch & McLaughlin, 1983) after, at least, a 10 minute exposure (Kaitz, Good, Rokem & Eidelman, 1987). Females, ranging in age from 5 to 99 years, appear to do better in odor identification tests than males (Porter et al., 1983).

Investigating sex differences in newborns, Balogh and Porter (1986) tested breast and bottle fed infants by exposing them to a familiar, (infant experienced a prior 23 hour exposure period with the odorant), versus an unfamiliar artificial odor (cherry or ginger). The results revealed that female infants displayed a significant orientation preference for the odor to which they had previously been exposed, whereas, the boys responded indiscriminately to the two odors and demonstrated a right-head turning bias, which was not observed with the girls.

Developmentally, as early as the second day of life, females, but not males, discriminate novel artificial odors and orient their heads for a longer duration to an odor they have previously experienced. However, the finding that girls orient longer to a familiar odor than boys was not replicated by Porter, Makin, Davis & Christensen (1991). Comparing two-week-old boys and girls these researchers demonstrated that the boys oriented longer toward the familiar odor. Presently, these age differences have not been explained.

Odor Hedonics

Adult psychological studies have shown that the most salient attribute of an odor is its hedonic valence. The measurement of odor hedonics has, until recently, taken a back seat to the psychophysical measures of odor intensity. Likewise, the bulk of the research on hedonics has been conducted on taste discrimination (Lipsitt, 1977; Rosenstein & Oster, 1988; Steiner, 1977).

Next, the ontogeny of odor hedonics from adulthood back to infancy will be traced.

Adults. Interested in the relationship between the emotional aspect of odors, Kraut (1982) conducted a study with adults whereby subjects were videotaped while they sniffed a number of odorants ranging in hedonic valence. Examining the videotapes, judges were quite successful in determining through the subjects' facial expressions, whether they had been exposed to a negative smell.

Further supporting the finding that odors have emotional components, Miltner, Matjak, Braun, Diekmann and Brody, (1994) found a relationship between the startle reflex amplitude and affective valence (odorants were subjectively equated for intensity). A negative odorant, hydrogen sulfide- H2, elicited a greater relative startle response amplitude than a positive odorant, vanilla.

Children. In a study conducted with children 5-12 years old, Soussignan and Schaal (1996) noted facial responses to odors and possible influences of hedonic valence, gender, sex, and social pressure. They found that girls exhibited more smiles than boys, but only when they were tested in a social situation and when the odorant was unpleasant. This study suggests that display rules, which are defined as social and cultural norms acquired during development, may operate to control facial appearance.

Testing younger children (three year olds) who might be less influenced by display rules, Schmidt and Beauchamp (1988) took into consideration attention, memory and language constraints and devised a technique that examined odor hedonics. The children were asked to give "good smells" to a likeable character from Sesame Street and "bad smells" to a grouchy television character. The results revealed adult-like odor preferences for a set of nine odorants (carvone, phenyl ethyl methyl carbinol, c-16 aldehyde, methyl salicylate, eugenol, amyl acetate, androsterone, butyric acid, and pyridine).

Infants. In order to ascertain the ontological development of odor hedonics, Steiner (1973, 1979) tested neonates, (12 hours old, with no prior, direct food experience). Odorants differed in their hedonic value which was subjectively determined by adults. The positive odorants included: diluted artificial butter, which closely resembled that of milk, vanilla, banana extract, and some fruity odors. The negative odorants included were: a fishy shrimp odor, as well as, an odorant resembling rotten eggs. Facial reactions were recorded and it was reported that food-related odors were appropriately evaluated in terms of their hedonic value in the first few hours of extrauterine life. Fresh or "good" food types elicited relaxation of the face and retraction of the angles of the mouth, resembling a smiling expression (banana, butter and vanilla elicited this response). In contrast, bitter or "bad" smells elicited facial expressions resembling aversion or disgust (shrimp and rotten eggs elicited this response).

For Engen, the classification of smells as "good' or "bad" is individualistic, determined by associations with the particular odorant. Engen and Lipsitt (1965) conducted a study with newborns, approximately 50 hours old, and found no evidence of preference or differentiation as measured by facial expression. All odorants (acetic acid, asafoetida, phenyl ethyl alcohol, and anise) appeared to elicit the same reaction of mild startle in the infant; whereas, most adults find one very pleasant and the other very unpleasant.

The data from Engen's lab failed to support Steiner's notion that odors have innate motivational properties. Providing a possible explanation for the discrepancy, Engen points out that the differential facial expressions reported by Steiner may have resulted from the smells' differing intensities, rather than their quality. In addition, some smells may have stimulated the trigeminal nerve which may have been responsible for the odorants' effects. This is not a minor point and will be raised in the discussion section.

Factors Affecting Odor Hedonics

Though many factors are said to have an affect on odor hedonics this discussion will focus on previous experiences with the stimuli and characteristics of the odorants themselves (intensity and temperature).

1) Postnatal Experience. Odor hedonics are influenced by repeated exposure (Cain & Johnston, 1978) in addition to the context in which the odor is presented (Murphy, 1982; Soussignan & Schaal, 1996). It has long been known (Beebe-Center, 1929) that odor hedonics are affected by what has previously been smelled. This appears to depend on whether there was prior experience with the particular odorant, or whether a pleasant or an unpleasant odor has just been smelled. In fact, after smelling a series of only pleasant odorants, the introduction of another pleasant smell seems not quite so pleasant as after smelling only unpleasant smells. Thus, the placement of the odorant, in relation to other odors varying in hedonics, is important. Madigan, Ehrlichman and Borod (1994) investigating the hedonic rating of odors as a function of odor sequence, detected a contrast effect whereby blocks of both pleasant and unpleasant odors were rated more hedonically intense when they followed exposure to odors of the opposite valence. They caution researchers against presenting odors of the same hedonic quality in blocks as this may bias the odorants' hedonic rating.

From animal literature, there exists evidence (Cheal, 1975; Kaplan, Cubicciotti & Redican, 1979) that when newborn rats are exposed to a certain odorant even one which is normally aversive, they come to prefer that odorant. Thus, early exposure sets up a later preference (Terry & Johanson, 1996).

It has been suggested that the detection of familiar odor cues may provide a feeling of security, as well as, a pacifying effect. Rosenblatt (1983) found that rat pups increase their distress cries and become agitated when placed in a washed nest site (absence of familiar smell) and, subsequently, settle down when returned to a familiarly scented nest area. Also studying rat pups, Hofer (1978) discovered that maternal odor cues seem to be essential in preventing autonomic symptoms of distress and in the regulation of a peaceful interaction between dam and pups. Similar relationships have been found in primates. Schaal has concluded that "all other sensory dimensions being held constant, alterations of the olfactory characteristics of the attachment object can thus cause fear and distress reactions in young primates" (1988, p.176).

Likewise, the familiarity dimension of the olfactory stimulus acts to reduce physiological, and behavioral arousal in human infants. This may be supported by the observation that a child's blanket, which serves as an attachment object, is endowed with a unique scent of the child's odors (saliva, tears, nasal-exudate) and has a calming effect. Psychotic and mentally disabled children, especially autistic children, have been noted to engage in frequent sniffing behaviors, perhaps providing a calming, pacifying effect to their otherwise over-aroused nervous system. However, exactly what this means is open to investigation.

From an evolutionary standpoint, it has been proposed that the preference for the familiar may be involved in the development of kin recognition (Hepper, 1987) and that unfamiliar odors are more often judged as unpleasant since the unfamiliar serves to alert, warn, and place the perceiver in a heightened state of arousal (Engen & Ross, 1973).

Well-documented in literature on animal suckling behavior, (Porter & Doane, 1976) is the fact that young are attracted to chemical signals (pheromones) produced by their lactating mothers. Kaplan & Russell (1974) conducted a study with 8-week-old squirrel monkeys and found that the olfactory modality is more salient than the visual one for early social discrimination and, ultimately, survival.

Studying humans, Macfarlane (1975) investigated the importance of biological odors in mediating early social recognition. He investigated neonate's head turning as an index of preference for the breast pad of their own breast-feeding mother as opposed to the pad from another mother. It was discovered that head turning was randomly distributed at 2 days of age, but at 6 days, the majority of the infants oriented their heads toward their mother's pad. This further confirmed research conducted by Lipsitt et al., (1963) that reported a decrease in the olfactory threshold within the first few days of life.

Investigating sucking behavior, Russel (1976) extended Macfarlane's (1975) finding that infants are more likely to orient and suck their own mother's breast pad. The infant at 8 weeks can, not only detect, but also discriminate between and prefer the smell of his/her own mother, as opposed to an unfamiliar lactating mother. When the odor cues were removed from the mother via washing, the infants' preferential behaviors were no longer apparent.

Mennella and Beauchamp (1991) investigated the effects of garlic ingestion by the mother on the odor of her breast milk and the suckling behavior of her infant. The results indicated that the nurslings detected the change in their mothers' milk and, in fact, stayed attached to the breast and sucked for longer periods of time than when the milk did not smell of garlic.

Makin and Porter (1989) investigated the responses of 57 infants to breast and axillary odors produced by lactating females. Two-week-old bottle fed girls responded preferentially to the breast odor of a nursing woman when it was paired with the woman's axillary odors.

Within the first few weeks of life, infants can recognize odors associated with their own feeding experiences and their behavioral response to certain odors varies according to their degree of prior exposure. It has been noted that the reinforcing value acquired by any post-natal olfactory stimulus may be positively related to the degree of similarity with odor stimulations accessible in utero (Schaal, 1988).

2) Intensity. Using psychophysical scaling experiments it has been documented that the hedonic value of an odorant tends to be inversely related to its intensity, the more preferred odor being the weaker one (Henion,1971). Reactions to unpleasant odors are more intense than to pleasant odors.

3) Temperature. Altering the temperature of an odorant appears to influence its hedonic value. In a study by Zajonc, Murphy & Inglehart (1989) subjects were asked to breathe what they thought were subtle odors and to rate the odors as pleasant or unpleasant. In fact, the air they breathed was either slightly cooled or heated but, unscented. The results showed that, when the subjects breathed the cool air, their forehead skin temperatures went down, and concurrently, they reported feeling positive. When the slightly heated air was presented, the subjects' forehead temperatures went up and they reported the stimulus as negative. The change in forehead skin temperature could be as subtle as .1 C.

Nasal Breathing and its Effects on Mood

Zajonc's Vascular Theory of Hedonic States (Zajonc et al., 1994) proposes that facial action and nasal breathing might alter the temperature of the blood entering the brain. The brain produces a considerable amount of heat and, therefore requires continuous cooling. Absence of this cooling is felt as discomfort while increased cooling is felt as pleasure. "Facial action can produce changes in the brain blood temperature, which in turn, has significant hedonic consequences. Such a process may in turn have subjective effects through its impact on the neurochemical activity in the brain (since neurochemicals are temperature sensitive)"(p.19).

In a typical experiment, Zajonc et al., (1989) used German subjects who were asked to read stories containing instances with the German umlaut (the phoneme u "ue"), which requires facial actions opposite to those of a smile. After reading the stories containing the umlaut, it was found that the subjects' forehead skin temperature was elevated and they reported feeling badly. In contrast, when they read other stories, their forehead temperature remained normal and their feelings were reported as unaffected.

The Nasal Cycle- side to side alternations in nasal patency

The nasal cycle dictates that the majority (80%) of healthy individuals alternate use of right and left nostril, devoting from 50 minutes to 4 hours, (with an average of 1 ½ hours), for each nasal cycle (Zajonc et al., 1994). Although most people are totally unaware of this fact, it has been reported (Principato & Ozenberger, 1970) that the obstruction is usually so complete that the total nasal airflow is mostly a function of the open nostril. The alterations occur as a consequence of partial congestion of the vascular epithelium lining the nasal turbinates in one nostril, with partial vasodecongestion in the other nostril (Menella & Beauchamp, 1992). The nasal mucosa is innervated by the sympathetic and parasympathetic systems which are regulated by the hypothalamus.

It should be mentioned that when infants and adults are given a choice between mouth or nasal breathing both exclusively select the nose (Rodenstein, Perlmutter, & Stanescu, 1985).

The Question of Differential Nostril Sensitivity. Koelga (1979) replicated an old study conducted in the early 1900's by Toulouse and Vaschide (cited in Koelga, 1979) which reported that the detection and sensitivity for n-amyl acetate were significantly higher for the left nostril, for both right-handed males and females. The few individuals whose right nostril was more sensitive were noted as being left-handed. However, Koelga's (1979) study found no such difference between the nostrils and Toulouse and Vaschide's findings are yet to be replicated.

The discrepancy between the studies may be the result of differences in the mode of response. It is possible that the subjects in the Toulouse & Vaschide study had to make a verbal response. Although, Koelga states that this is only a hypothesis since the original study did not specify how the subjects were to respond. In contrast, in Koelga's study the subjects were to respond according to a 4-alternative forced-choice method of constant stimuli, not demanding the use of language and, presumably, the left hemisphere. Koelga adds that "if [*sic*] future studies of olfaction no difference in sensitivity between the right and left hemispheres may be found, it might be that the differences in olfactory sensations may exist where verbal and emotional factors play an associative role, as in experiments on recognition or identification, familiarity, memory and preference " (Koelga, 1979, p.94).

In a study conducted with adults, Ehrlichman and Halpern (1988) compared left and right nostrils' ratings of pleasantness and unpleasantness and reported that only the negative odors showed a laterality effect. This study was limited to males.

Rationale of the Studies:

The current studies were conducted on healthy (see criterion below) infants to determine if olfaction could be used in assessing emotional laterality. The infants were tested during sleep. Past studies have shown that adults (Badia, Wesensten, Lammers, Culpepper & Harsh , 1990) and infants (Murray & Campbell, 1970) are reactive to odorants during sleep. The dependent measures were spontaneous facial and body movements: sucking behaviors (rhythmic mouth movement up and down), head and hand movements. Facial and body movements are frequently used measures of emotional expression. The stimuli used to elicit the responses were positive and negative food-related odors. Different expectations derive from the major hypotheses concerning cerebral lateralization. If the **Valence Hypothesis** is correct, then, when the **negative** odors are presented to the **right** nostril (right hemisphere), there would be more of a response than when the same odorant is presented to the left nostril (left hemisphere). Conversely, when the **positive** odors are presented to the **left** nostril, there would be more of a response than when these same odorants are presented to the right nostril. If the **Right Hemisphere Hypothesis** is correct, then when the odors, regardless of their valence, are presented to the **right** nostril, there would be more of a response than when the same odorants are presented to the left nostril.

Two studies were conducted. Study 1 tested 60 newborns of both sexes. Study 2 emerged from Study 1 and tested an additional 20 infants. Once it was determined from Study 1 that neonates responded to odors verses a control, the various hypotheses raised in the introduction were examined.

Method

Study 1

Subjects

Sixty full term healthy infants were recruited from the newborn nursery of Albert Einstein Hospital. The infants' mothers provided written consent prior to testing. In order for the infant to be included in the study, the following criteria had to be met. (1) Medically uncomplicated full-term pregnancy. (2) Medically uncomplicated spontaneous or pitocin-induced vaginal delivery with no indication of drug use. (3) Birth weight of at least 2500 grams. (4) Apgar score (Apgar, 1953) of at least 7 at 1 minute, and at least 8 at 5 minutes. (5) Normal and healthy on pediatric examination. (6) Completion of at least 30 of the 37 trials. (7) Finally, infants had to be in state 1 or 2 of sleep according to Prechtl's criteria described below (1982). Adhering to these criteria, the actual number of infants who contributed data to the study was thirty-two (16 females and 16 males).

The demographics of the subjects were as follows. The males included in the study were either uncircumcised (9) or, were tested at least 2 hours after circumcision. The mean age for the girls was 22.5 hours, while the mean age for the boys (both circumcised and uncircumcised) was 15.2 hours. Forty-four percent of the males were breast-fed, 44% bottle-fed and the remaining 12% were both breast and bottle-fed. Forty-four percent of the girls were breast-fed, 38% bottle-fed and the remaining 18% were both breast and bottle-fed.

Stimuli

Two positive smells, vanilla (P1) and almond (P2) and two negative smells, rotten eggs (N1) and sour milk (N2) were used. The positive smells were obtained at the Body Shop and prepared in a non-alcoholic base. The negative smells were prepared by the experimenter. The egg (boiled) and milk were set in a warm room and allowed to decay for a week. The hedonic nature of the odorants was determined subjectively by four adult raters. The odorants were also equated subjectively in terms of intensity (described below). The control stimulus was distilled water placed on a cotton ball. The stimuli were stored in separate air-tight bottles, stoppered with a cork. All odorants have been safely and successfully used by previous researchers (Steiner, 1979; Ehrlichman & Halpern, 1988; Ehrlichman, 1987; Wood & Harkins; 1987).

Response to each stimulus condition was analyzed for the entire 10 second duration of the trial. The trial was extended for 10 seconds because latencies this long are sometimes obtained with infants (Muir, 1985). Response was rated in terms of a three category checklist: head movement (any movement of the head either to the right or left or back or forward), hand movement (if unswaddled, defined as any movement of the right or left hand) and sucking (defined as rhythmic lip movements) behaviors.

Procedure

Each infant was tested individually while lying supine in a standard hospital bassinet. Testing occurred at the mother's bedside within the first 24 hours of birth. Infants' faces were videotaped throughout the 40 minute session (with a portable Panasonic videotape recorder equipped with a zoom lens), with the camera mounted on a tripod approximately 2 feet from the top of the bassinet.

Infants were tested while in either state 1 or state 2 of sleep as determined by a modified version of the Prechtl (1982) scale. According to Prechtl's criteria (1982) state 1 is defined as regular sleep where the respiration is regular, eyes are closed, and no movement occurs except for an occasional startle; state 2 is defined as irregular sleep where the eyelids are closed and eye movements are rapid. Since the state of sleep could not be controlled and the testing sessions lasted about forty minutes, most infants did not remain in the same state (1 or 2) of sleep throughout testing.

Testing began 60-150 minutes after feeding since it has been shown that the effect of a food odor is modulated by the nutritional state of the infant (Cabanac, 1971).

Each infant was presented with the 2 positive and 2 negative odorants. An unscented air stream was utilized as the control. In all cases, each of the four odorants was paired with the control. Each pair was presented two times, once with the odorant delivered to the right nostril and once with the odorant delivered to the left nostril. These 8 trials were repeated in 4 blocks making a total of 32 trials.

Five control trials, where a puff of air to both nostrils was administered, were included. Four of these trials were randomly distributed in the 4 blocks. The remaining control trial was always presented as the first trial in the series to familiarize the infant with the delivery system. Thus, the total number of trials was 37. The presentation of the odorants was completely counterbalanced. Infants were randomly assigned to one of four sequences. Sequence 1 first received the negative odorant below the right nostril. Sequence 2 first received the negative odorant below the left nostril. Sequence 3 first received the positive odorant below the right nostril. Finally, sequence 4 first received the positive odorant below the left nostril. In order to minimize habituation to the odorants, the presentation time of each smell was under 5 seconds. (The diffusion time for a typical odorant through 35 nm of olfactory mucus is about 300 msec, not taking into account the time required for the odorant to reach the critical concentration required to initiate a response, Getchell & Getchell, 1980). The interstimulus interval was at least 30 seconds, or until the neonate returned to a neutral expression, since differential facial expression was explored as a possible dependent variable.

The odorants were placed on cotton balls. The cotton balls were then housed in sterile 12 cc surgical syringes with thin sterile tubing attached in place of a needle. The odorants were kept at room temperature.

To help keep the odorants in position under the appropriate nostril, the tubing was threaded into a block of plastic that the experimenter held (see Figure 1). (Note: in Study 2 an additional plastic block was inserted between the two pieces of tubing. This improvement in the delivery apparatus further prevented the smells of either tube from diffusing across to the opposite side).

Figure 1. Olfactory Apparatus.

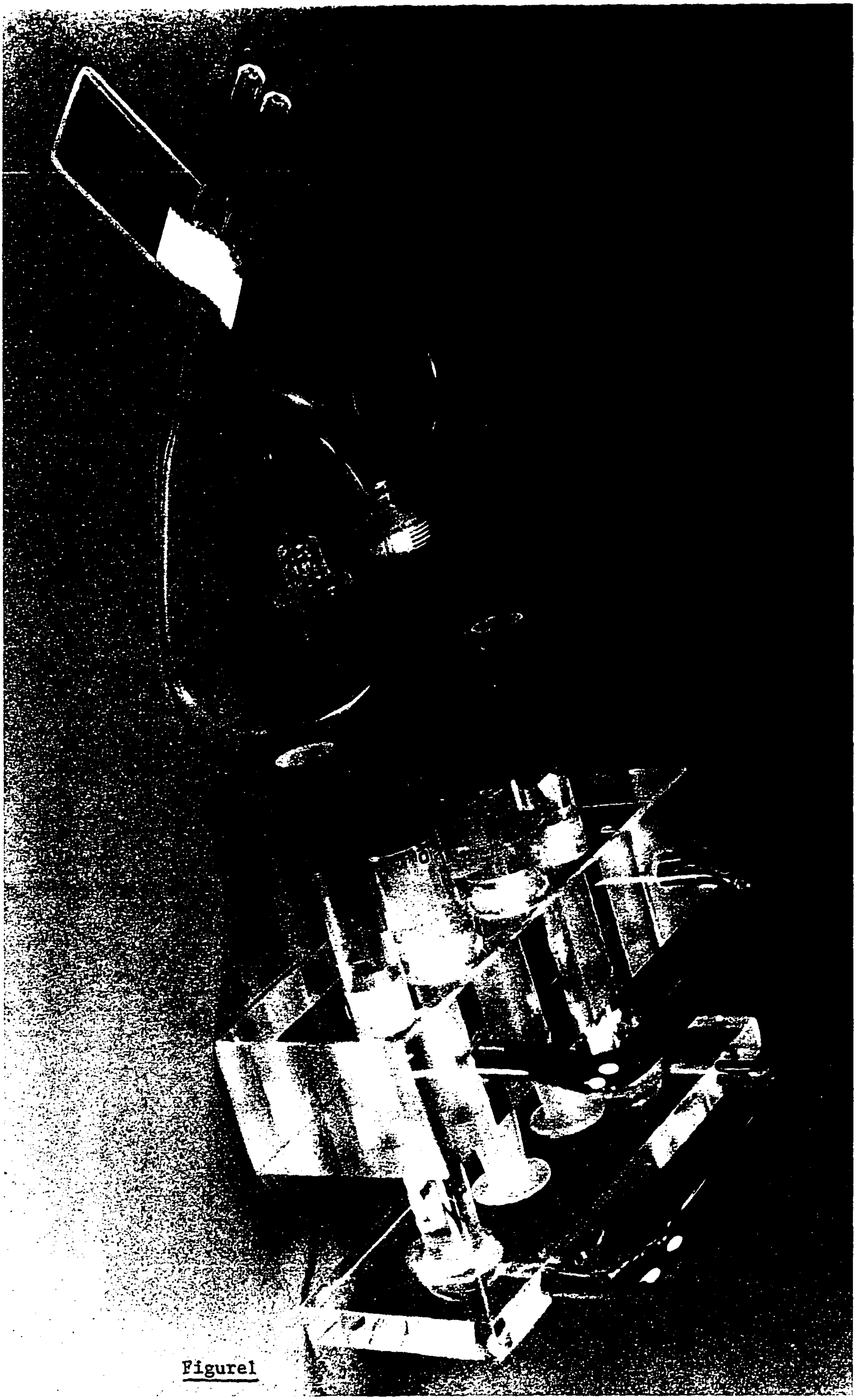

Figure 1

Measurements

Videotape coding and analysis:

Initially, the experimenter and her assistants (two right-handed females) viewed all the video recordings with the instructions being to rate the faces according to whether a response was present or not (the focus was not on specific facial features i.e, sucking movements). Since a "response" was never precisely defined, agreement across raters ranged from 70% to 100%. Thus, the experimenter, after again looking at all the tapes, compiled a list of all possible behavioral responses. From this list, a determination was made (based upon a frequency count) as to the most prevalent behaviors; and the focus of attention for the raters was narrowed. Next, three raters (blind to the smell category) were given a table which listed the following three behaviors: (head movement, hand movement, if unswaddled, and sucking behavior) and told to check for each of the 37 trials per baby whether or not the above behaviors occurred. The coders viewed all the videotapes three times. Time 1, they were told to restrict their attention to the mouth area; time 2, to head movements, and, finally, time 3, to hand movements. In terms of the final coding of a response, if at least 2 out of the 3 raters agreed that a response had occurred, that trial received the number 1; otherwise, it was assigned a 0.

Reliability

Reliability tests (Kappa) for non-parametric statistics were conducted comparing the ratings of three judges on the following behaviors: head, hand movements, and sucking. Thus, interrater reliability was determined for the thirty-two infants on the three dependent measures. The kappa coefficient was computed over trials and an average was taken for the neonates. The kappa values were: for head movement k=.2506 (Z=7.92); for hand movement k=.2603 (Z=9.62);and for sucking k=.4029 (Z=11.42). These reliabilities are considered moderate in value (Siegel & Castellan, 1988).

In addition, interrater reliability was determined among the three raters. The percent agreements for the three dependent measures: head, hand and sucking movements respectively were as follows: raters 1 and 2, 93%, 95%, and 94%., raters 1 and 3, 86%, 94%, and 85%, and raters 2 and 3, 91%, 89% and 89%.

Response Rating

Odorant Screening-

The intensity of the odorants was subjectively equated (via 4 adult raters) so as to minimize any differences that might be produced by differences in intensity. Intensity of each odorant was coded with the following 7-point rating scale: 1 =extremely unpleasant, 2 =moderately unpleasant, 3 = slightly unpleasant, 4 =neutral, 5 =slightly pleasant, 6 =moderately pleasant and 7 =extremely pleasant. Each odorant was presented ten times. The raters agreed 80% of the time that the odorants were in the moderate range (3 & 6). In addition, the odorants were screened for a trigeminal element.

Because the trigeminal nerve (fifth cranial nerve) has contralateral pathways to the brain it was necessary to determine if any of the odorants stimulated the trigeminal nerve thereby confounding the results. This screening was accomplished in the following manner. In accordance with a procedure used by Madigan, (personal communication, 1996), ten adults tested the odorants. Each odorant was placed in an apparatus similar to that in Figure 1 except fitted for an adult. The subjects' task was to determine which nostril was receiving the smell. The rationale was that if an odor contained a trigeminal component, the subject would be able to localize which nostril was receiving it. Odorants possessing trigeminal elements are experienced as irritating. Each of the 4 smells was presented 10 times. In addition, a known trigeminal stimulant, mint, was also presented 4 times. Mint was identified as going towards the correct nostril 80% of the time. Vanilla (P1) was localized correctly 50% of the time. Almond (P2) 40% of the time. Rotten eggs (N1) 50% of the time, and, finally, sour milk (N2) 40% of the time. Thus, the odorants used did not appear, by this procedure, to possess any significant trigeminal component according to these adults.

Results

In order to determine whether the infants were reacting to the smells as opposed to the stream of air, t-tests, comparing infants' responses on stimulus verses control trials were conducted for each response measure. Since the number of stimulus trials (8) was not equal to the number of control trials (5), comparisons between the two could not be made until the following mathematical corrections took place. First, the four odorant trials, (PR, Pl, NR, NL), were added together and divided by four. Each control trial was then multiplied by a conversion factor (8/5) to correct for the unequal number of trials.

Analyses revealed that the infants were, in fact, responding more frequently on odorant than on the control trials. As seen in Table 1, responses were infrequent to the control trials.

Preliminary analyses comparing the 2 positive and the 2 negative odorants did not reveal any differences therefore, they were combined on all subsequent analyses. In order to examine the effects of several response variables, multivariate analyses (MANOVA), in which Sex (between subject factor) X 3 within factors: Movement (head, hand or sucking), X Nostril (right or left), X Odor Valence (positive or negative), were conducted. There were no main effects for Odor Valence or Nostril. The interactions for Odor Valence x Nostril approached significance (F =3.62; df=1,25; p<.06). As seen in Table 2 when the positive odorants were presented to the left nostril slightly more responses occurred (mean= 2.0) than when presented to the right nostril (mean= 1.8). The means represent the number of times the response occurred which ranged from 0 to a total of 4. When the negative odorants were presented to the right nostril slightly more responses occurred (mean= 2.1) than when presented to the left nostril (mean= 1.9). There was a suggestion that the nostril to which the odor was presented and the odor valence may make a difference. Additional testing revealed a significant Movement x Nostril interaction (F= 5.21; df=2,50; P<.01), indicating that the type of movement the neonate made depended on the nostril that was stimulated. As depicted in Table 3, slightly more sucking occurred when the smells went to the left nostril as compared to the right. Also, slightly more head and hand movements occurred when the smells went to the right nostril as opposed to the left. The dependent measures were apparently not assessing the same emotional component (see correlational analysis below). A t-test revealed a significant difference only for sucking behaviors. More sucking occurred when the smells went to the left nostril (mean=1.86) as compared to the right nostril (mean=1.49).

It is of note to mention that 24 of the 32 neonates were lying on their right sides while being tested. Five infants were lying on their left sides and the remaining three were positioned at midline.

Table 1. Mean Number of Responses Made to Control verses Odorant

Dependent Measure	Stimulus	Mean*	Standard Error	*t*	p
Head	Control =	1.25	.364	2.29	.05
	Odorants =	2.25	.216		
Hand	Control =	1.05	.325	2.41	.05
	Odorants =	1.84	.226		
Sucking	Control =	.550	.255	4.28	.01
	Odorants =	1.67	.156		

* range 0 to 4

Table 2. Odor Valence by Nostril Interaction Collapsing over Movement

Condition	Mean*	Standard Deviation
Positive/Right	1.8	1.36
Positive/Left	2.0	1.54
Negative/Right	2.1	1.53
Negative/Left	1.9	1.55

*Means are out of 4

Table 3. Movement by Nostril Interaction Collapsing over Odor Valence

Condition*	Mean	Standard Deviation
Sucking/Right	1.49	1.38
Sucking/Left	1.86	1.54
Hand/Right	1.94	1.46
Hand/Left	1.77	1.08
Head/Right	2.33	1.50
Head/Left	2.17	1.77

*Right or left nostril

Means are out of a total of 8

Correlations among Dependent Measures

In order to examine the relationship among the three dependent variables (hand, head and sucking movements) intercorrelational matrices were computed to determine if in fact they were measuring the same affective component. The correlation coefficients were all low and non-significant, indicating an independence of measures.

Sex Differences

Since past studies have demonstrated sex differences in emotional expression, separate ANOVA's were conducted for the male and females, even though there were no main effects or interactions for sex found in the MANOVA. Separate two-way ANOVA's for each measure (ie., head, hand and sucking movements) with Nostril (right/left) and Valence (positive/negative) as factors were performed. These failed to reveal any significant effects or interactions. The relevant means and standard deviations are presented in Tables 4-9.

Table 4. Mean Number of Hand Movements made by Females

Condition *	Mean	Standard Deviation
Positive/Right	1.77	.89
Negative/Right	2.54	1.55
Positive/Left	1.92	1.07
Negative/Left	2.62	1.64

*Valence/Nostril

Means are out of 4

Figure 2. Mean Number of Hand Movements made by Females (± 1 SE).

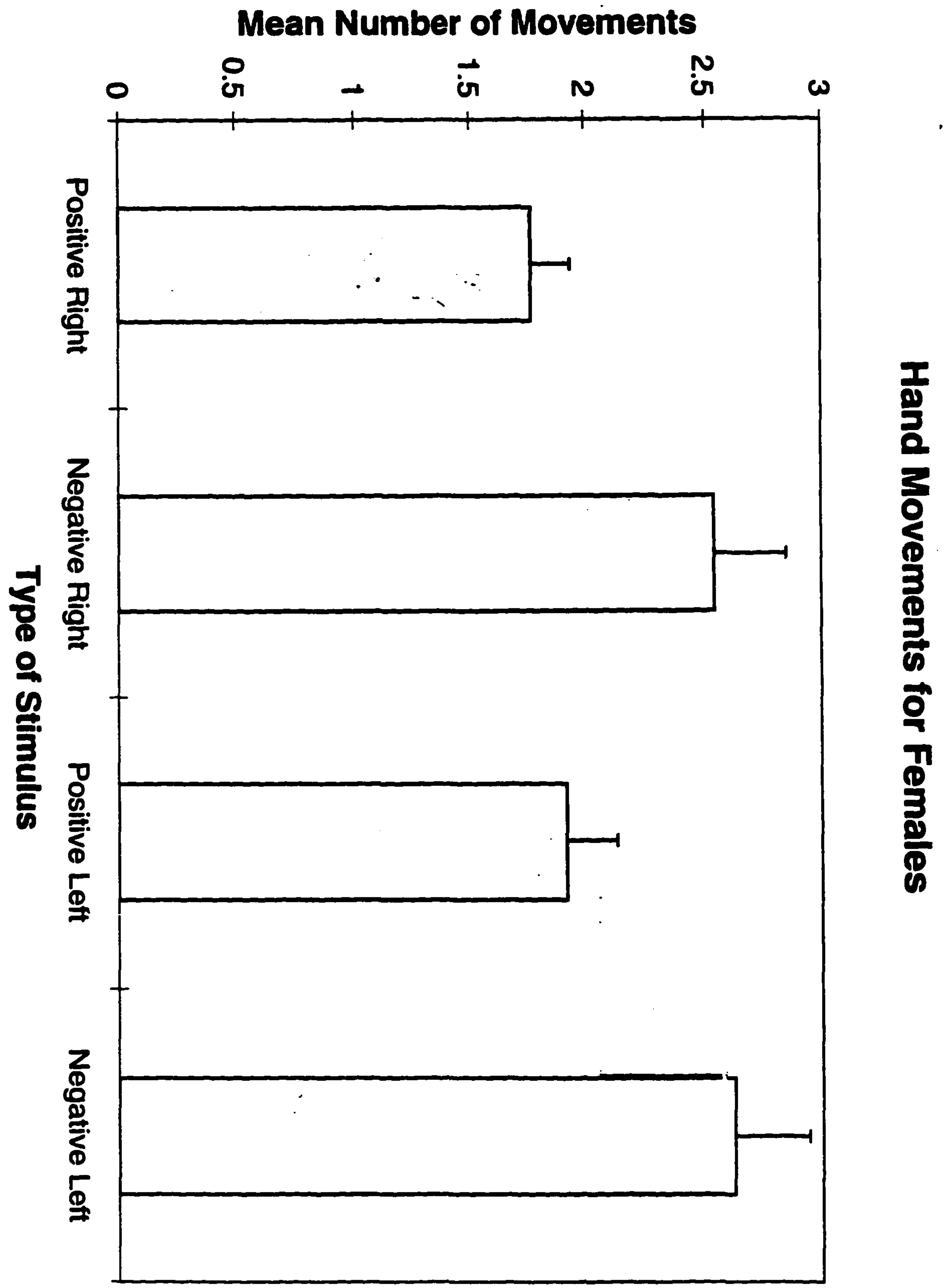
Hand Movements for Females
Mean Number of Movements
0
0.5
1
1.5
2
2.5
3
Positive Right
Negative Right
Positive Left
Negative Left
Type of Stimulus

Figure 2

Table 5. Mean Number of Hand Movements made by Males

Condition *	Mean	Standard Deviation
Positive/Right	1.46	1.60
Negative/Right	2.00	1.80
Positive/Left	1.54	1.39
Negative/Left	1.01	1.21

* Valence/Nostril

Means are out of 4

Figure 3. Mean Number of Hand Movements made by Males (± 1 SE).

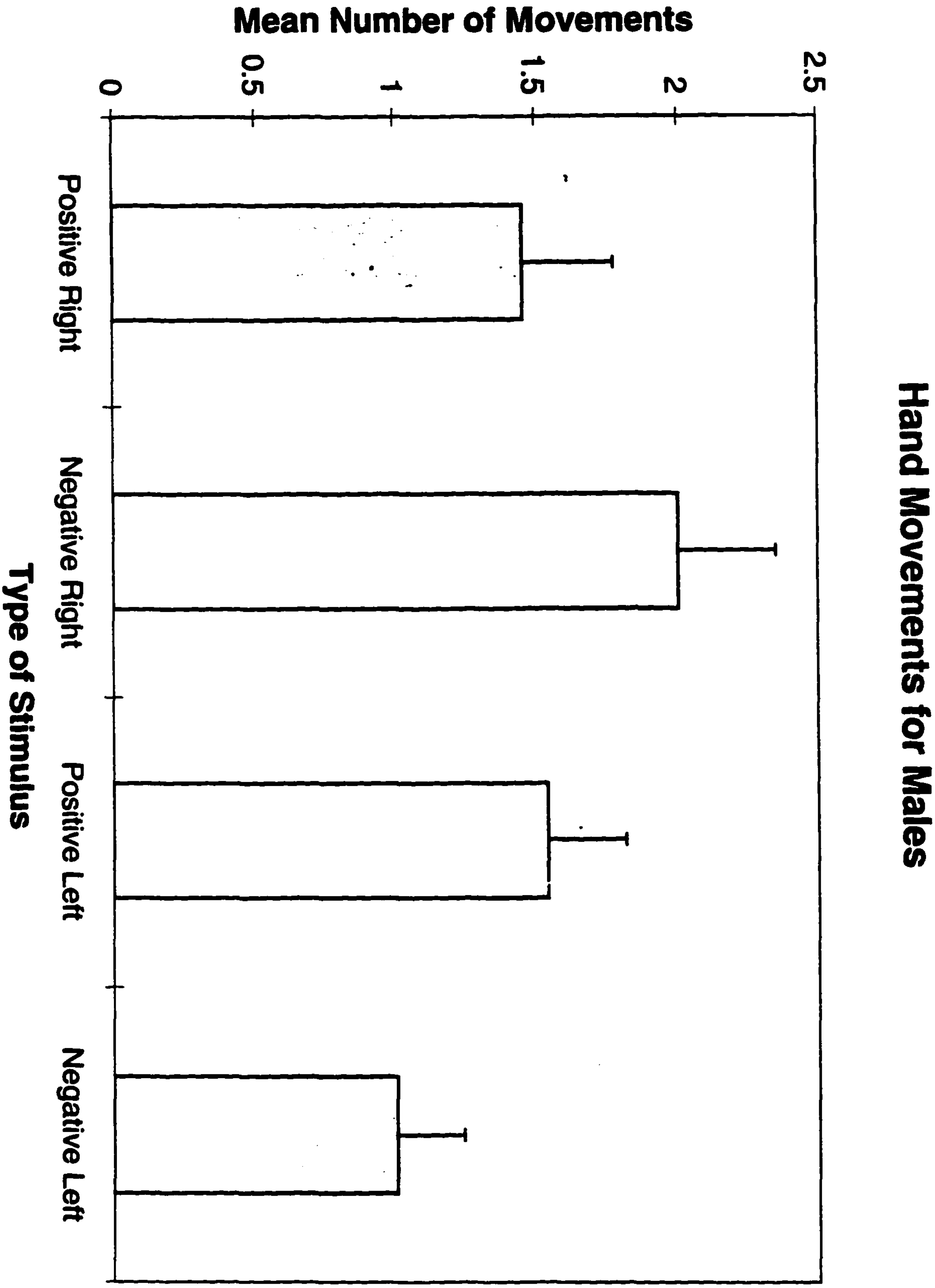
Hand Movements for Males
Mean Number of Movements
0
0.5
1
1.5
2
2.5
Positive Right
Negative Right
Positive Left
Negative Left
Type of Stimulus

Figure 3

Table 6. Mean Number of Head Movements made by Females

Condition *	Mean	Standard Deviation
Positive/Right	2.06	1.60
Negative/Right	2.19	1.81
Positive/Left	2.06	1.85
Negative/Left	2.31	1.65

*Valence/Nostril

Means are out of 4

Figure 4. Mean Number of Head Movements made by Females ($\pm$ 1SE).

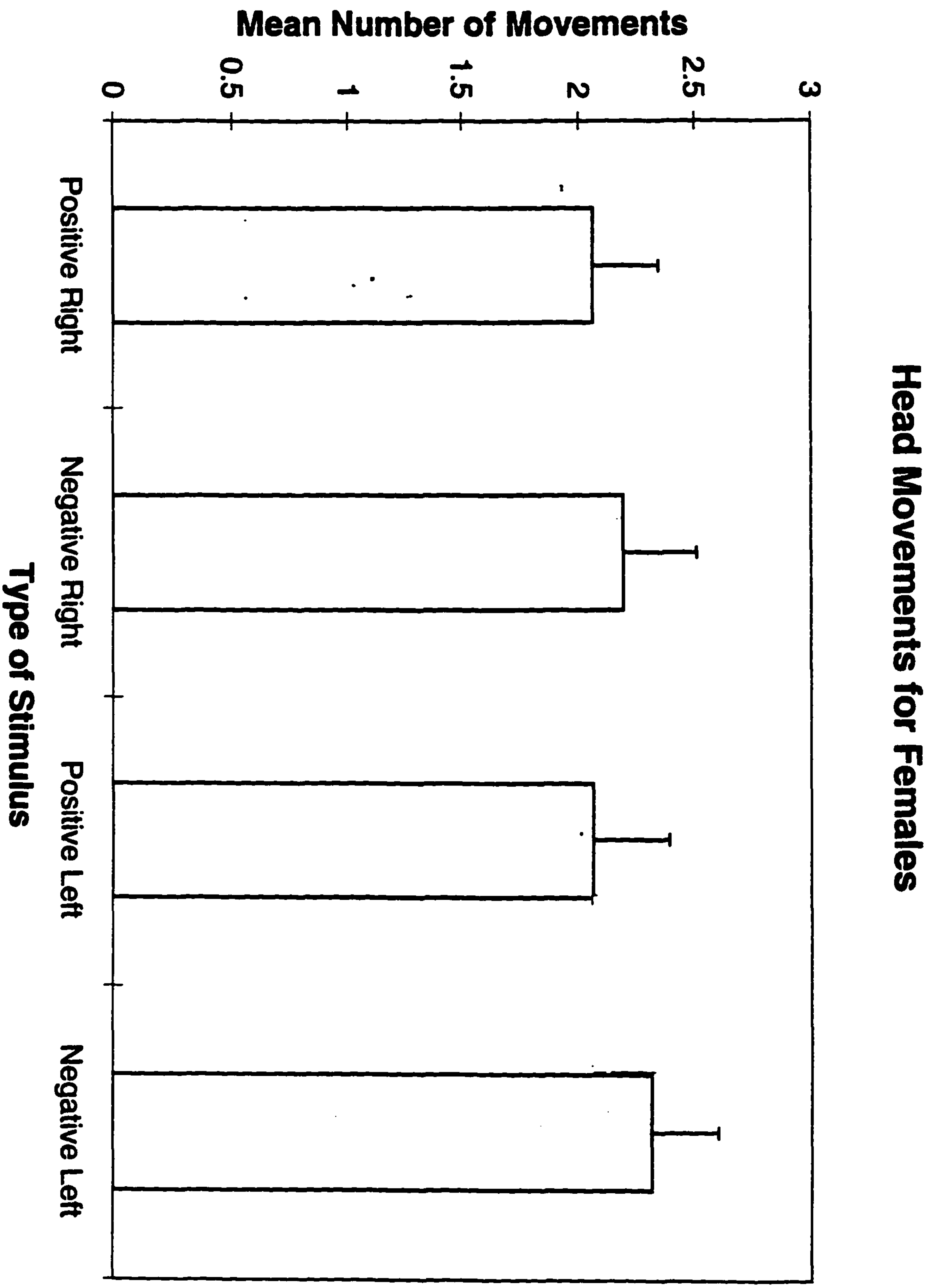
Head Movements for Females
Mean Number of Movements
0
0.5
1
1.5
2
2.5
3
Positive Right
Negative Right
Positive Left
Negative Left
Type of Stimulus

Figure 4

Table 7. Mean Number of Head Movements made by Males

Condition*	Mean	Standard Deviation
Positive/Right	2.50	1.32
Negative/Right	2.56	1.22
Positive/Left	2.69	1.86
Negative/Left	1.63	1.73

* Valence/Nostril

Means are out of 4

Figure 5. Mean Number of Head Movements made by Males ($\pm$ 1 SE).

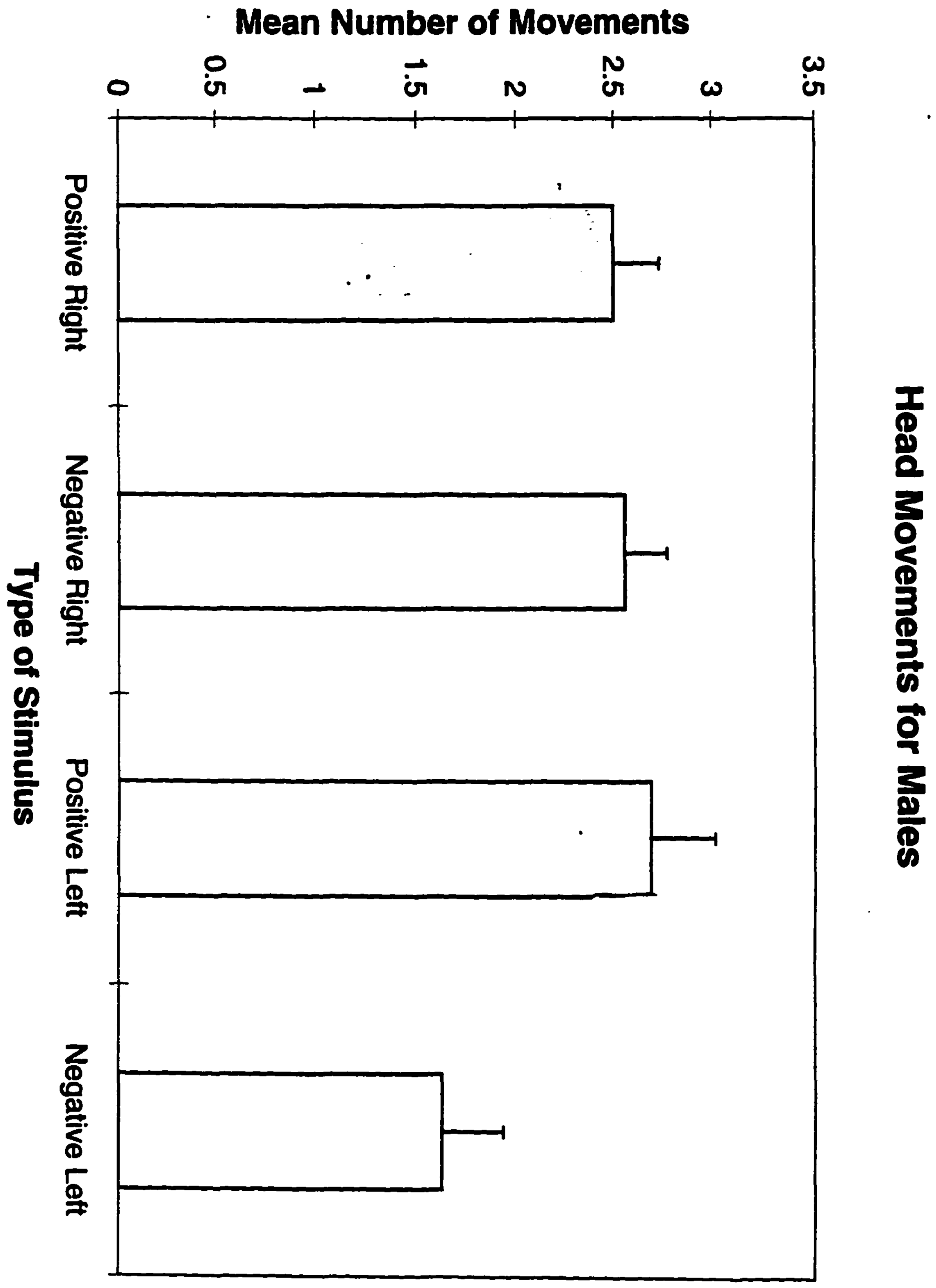
Head Movements for Males
Mean Number of Movements
0
0.5
1
1.5
2
2.5
3
3.5
Positive Right
Negative Right
Positive Left
Negative Left
Type of Stimulus

Figure 5

Table 8. Mean Number of Sucking Movements made by Females

Condition *	Mean	Standard Deviation
Positive/Right	1.50	1.58
Negative/Right	1.44	1.84
Positive/Left	1.94	1.52
Negative/Left	1.88	1.58

*Valence/Nostril

Means are out of 4

Figure 6. Mean Number of Sucking Movements made by Females ($\pm$ 1 SE).

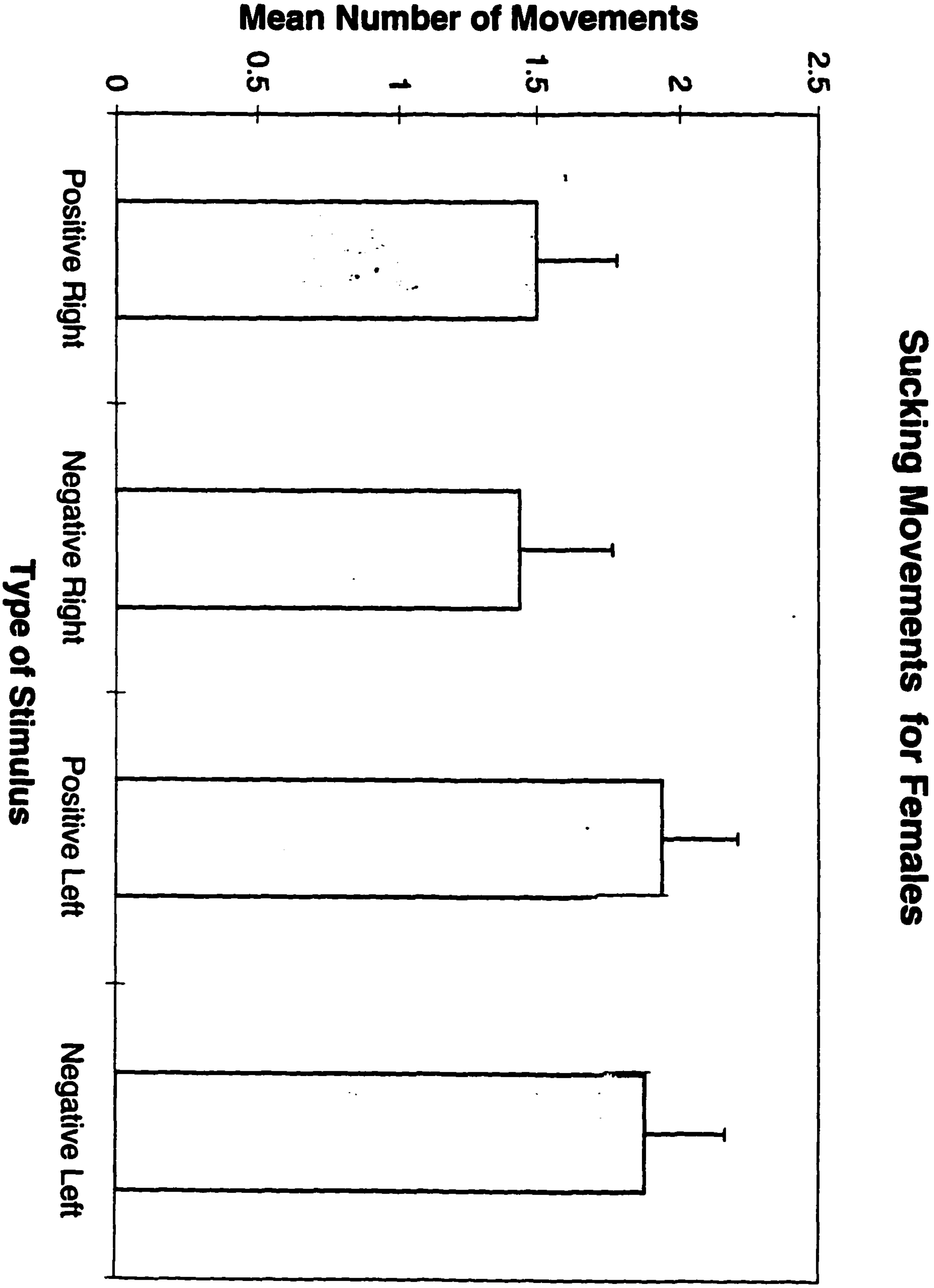
Sucking Movements for Females
Mean Number of Movements
0
0.5
1
1.5
2
2.5
Positive Right
Negative Right
Positive Left
Negative Left
Type of Stimulus

Figure 6

Table 9. Mean Number of Sucking Movements made by Males

Condition *	Mean	Standard Deviation
Positive/Right	1.44	1.17
Negative/Right	1.56	.93
Positive/Left	1.94	1.56
Negative/Left	1.69	1.49

*Valence/Nostril

Means are out of 4

Figure 7. Mean Number of Sucking Movements made by Males (± 1SE).

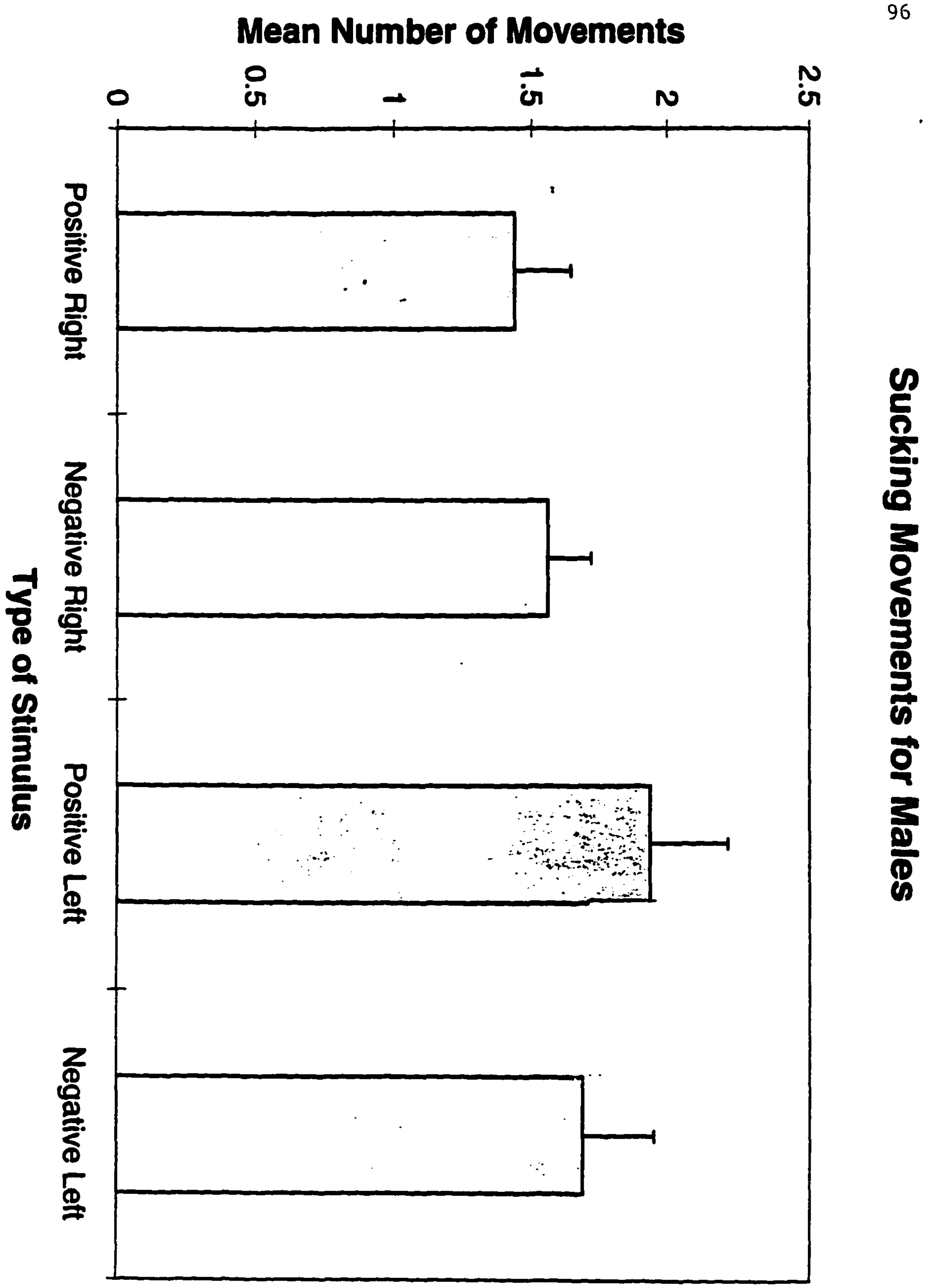
Sucking Movements for Males
Mean Number of Movements
0
0.5
1
1.5
2
2.5
Positive Right
Negative Right
Positive Left
Negative Left
Type of Stimulus

Figure 7

Discussion

The results of this study confirm that neonates exhibit increased head, hand and sucking movements in response to odors. Thus, it appears that newborns, prior to any postnatal experience, can discriminate a scented air stream from an unscented stream. These results are in accord with those of Sarnat (1978). The second, and somewhat surprising finding, was that more sucking behavior occurred when smells were presented to the left hemisphere, than to the right. According to several hypotheses one might expect more sucking to olfactory stimuli presented to the right than to the left hemisphere.

Three possible explanations are offered in interpreting these results.

Interpretation 1- Effect due to a confound

Infant head position may have confounded the obtained results. The majority (75%) of the infants were lying on their right sides prior to and throughout the experiment. This head-right posture may have altered the nasal cycle producing a bias for left nasal breathing thus, activating the left hemsiphere.

During the nasal cycle individuals alternate between breathing through their right and left nostrils. In order to activate a particular nostril, one should lie on the opposite side to the occluded nostril (Rama, Ballentine & Ajaya, 1993). This is presumably due to the force of gravity exerted on the nasal vasculature. The right nostril may have been occluded due to mucosal vasocongestion which prevented the odorants from reaching olfactory receptors.

The delivery apparatus may have presented another potential confound. As seen in Figure 1 the apparatus delivering the odorants may have diffused some of the odorant to the unintended side, rather than confining it to one nostril. Permission was not granted to insert the device in the neonates nostrils; therefore it had to be held underneath and not touching the nostrils.

Interpretation 2- The odorants possessed a trigeminal component.

As mentioned in the methods section, the odorants were screened, albeit subjectively, for trigeminal components. All odorants were of a low intensity as judged by adults. However, if the trigeminal nerve was activated the interpretation would be the reverse of those reported. Due to the trigeminal system's contralateral innervation, more sucking would have occurred when the smells were directed to the right hemisphere than to the left. This possibility must be raised since researchers are presently in disagreement as to the extent of the trigeminal system's contribution to and interaction with the olfactory system. The implications of the claim that there are no pure olfactory stimuli (Silver & Maruniak, 1981) would warrant reevaluations of studies on the lateralization of olfaction.

Electrophysiological studies may be able to shed some light on this fundamental question.

Interpretation 3- Infant emotional responses (i.e.,sucking behaviors) are lateralized to the left hemisphere.

The interaction of Odor Valence X Hemisphere approached significance. Upon closer examination of the means for each sex the greatest number of sucking behaviors occurred when the positive smells were directed to the left nostril. Since smell and taste are so intricately linked, it is likely that the food-related odorants (especially the positive ones) elicited sucking responses. Taste-smell confusions, whereby olfactory stimuli evoke sensations of taste, are commonly reported in the literature (Murphy & Cain, 1980).

The finding that neonates engaged in more sucking behaviors when positive smells were directed to their left nostrils contradicts past studies reporting more sucking in response to negative stimuli. Some researchers claim that non-nutritive sucking alleviates stress and pacifies the neonate (Dipietro, Cusson, Caughy, & Fox, 1994). However, Steiner (1979) reported that newborns exhibited increased sucking and a "smiling" expression when exposed to a vanilla odorant. A number of reasons contribute to the conflicting findings on neonatal non-nutritive sucking. Comparisons across studies are difficult since researchers have examined different temporal components i.e., duration of sucking bouts, cumulative pausing time, inter-response time, inter-burst interval, number of bursts, number of responses to burst and mean number of responses. Furthermore, the assessment of sucking has taken place within different behavioral states. State related differences also influence and confound reactions.

It remains for future research to determine if increased sucking occurs when positive smells are directed to the left hemisphere or if the finding was due to an experimental confound. If sucking frequency reliably increases when positive odors are presented to the left hemisphere one possible function of this behavior may be to reduce brain temperature (significance discussed in Study 2) hence its association with pleasure. Also, mouth movements may retronasally influence the intensity of the odorant (Burdach & Doty, 1987).

Study 2 was conducted for two reasons. The first was to replicate the findings that neonates respond to odors verses a control. Second, and more important, was to examine the hypotheses regarding emotional lateralization. Evaluating the hypotheses required neonates make a directional response from a starting midline position. In Study 1, the majority of neonates were lying on their right sides; this may have produced preferential left nostril breathing. To eliminate this bias in Study 2, newborns' heads were placed in a midline position at the start of each trial. Attention was focused on head movements in response to unilateral presentations of smells. This gave newborns the opportunity to make directional head turning responses towards or away from the odorants thus testing the Right Hemisphere, Valence and Appproach-Withdrawal Hypotheses.

Method

Study 2

Subjects

Twenty full term healthy infants were recruited from the newborn nursery of Albert Einstein Hospital. The infants had to meet the same criteria as in Study 1. The final number of subjects in Study 2 was reduced to 10 (7 females, 3 males). This reduction in sample size occurred either because the infants woke up (7), or the mothers were having visitors and requested the experiment be terminated (3). The mean age for the girls was 20.2 hours and for boys 16.4 hours.

Stimuli

The stimuli used were the same as those employed in Study 1, although the apparatus was slightly modified by inserting a plastic block in between the hand-held nose piece. This prevented diffusion of the odorant to the unintended side.

Procedure

The procedure employed in Study 2 followed that used in Study 1 with the following exceptions. Prior to the administration of the odorants, the infant's head was held at midline. This was accomplished in the following manner. The experimenter gently shifted the baby's head and body, which was usually turned to the right (75% of the time), to the middle and held this orientation until the baby maintained it by him/herself. Unfortunately, this frequently lengthened the time it took to test the babies and sometimes altered the babies' behavioral state (for example: from state 1 sleep to an awake state). For this reason, it became necessary to reduce the total number of trials from 37 to 20 (each odorant, the 2 positive and 2 negative odors, and the control were presented 4 times).

Measurements

Videotape coding and analysis:

For this study, attention was focused on determining if there was any differential head movement when the head was released from a midline starting position. Head movement was rated for each trial in terms of two directions: to the right or left. An infant was classified as having turned its head to either the right or left when by visual inspection its head position detectably deviated from the starting midline position. Only the initial head movement was recorded. To maintain consistency between Study 1 and Study 2, three raters, blind to the odorant presented and the nostril to which it was presented, separately coded the videotapes. If at least 2 out of the 3 raters agreed that a head movement had occurred that particular trial was assigned a 1; otherwise, a 0 was assigned.

Reliability

Inter-rater reliabilities were assessed among the raters for head movements. Raters 1 and 2 agreed 84% of the time. Raters 1 and 3 agreed 94% of the time. And, finally, raters 2 and 3 agreed 90% of the time.

Results

In an attempt to replicate the findings of Study 1, where infants were responded to odorants as opposed to the air stream, a paired t-test was conducted comparing infants' head responses on the 16 stimulus and 4 control trials. Because there was an unequal number of control verses odorant trials the following mathematical corrections were made. The four odorant trials (PR, PL, NR, NL) were added together and divided by 2 since this represented the number of times the trials were presented. Next the control trials were multiplied by a conversion factor of (8/4).

Analyses revealed that, as in Study 1, the infants responded more frequently to odorants than to control trials. In terms of overall head movements, the infants responded significantly more to the smells (mean = 2.1, sd= 1.3) than to the control (mean = .6, sd= .66), $\underline{t}$ (9)= 2.87, $p<.05$. Comparing the odorant means from Studies 1 and 2, it is noted that they are slightly higher in Study 1.

In order to address the main issue of hemispheric specialization of emotions, Study 2 added the requirement that neonates' heads be held at midline at each trial's start. Thus, directionality of head movement entered into the picture and the following analyses were conducted. First, a paired t-test was conducted on the control trials to determine if, in fact, there was a difference between left or right head turns. Results revealed that although there were slightly more right head turns (mean=.30) than left head turns (mean=.20), this difference was not significant t (9) = 1.15, p>.05. (Means could range from 0 to a total of 4).

To examine the rival hypotheses, a 2x2x2 MANOVA with Odor Valence (positive, negative) x Nostril (right, left) x Direction (towards, away) was performed on the data. For purposes of simplicity the following abbreviations will be used: P=positive, N=negative, R=right nostril, L= left nostril, T= head turn towards and A= head turn away. For example: PLT specifies head movements towards positive odorants presented to the left nostril. In order to facilitate relating the results to the two main hypotheses, the predictions for the various stimulus contributions are outlined in Table 10.

According to the **Valence Hypothesis**, the infants should turn towards a positive stimulus directed to their left nostril (PLT) more frequently than towards a positive stimulus directed to their right nostril (PRT). More away head turns should occur when a negative stimulus is directed to their right nostril (NRA) than to their left nostril (NLA).

According to the **Right Hemisphere Hypothesis**, the infants should turn towards a positive stimulus directed to their right nostril (PRT) more frequently than towards a positive stimulus directed to their left nostril (PLT). More away head turns should occur when a negative stimulus is directed to their right nostril (NRA) than to their left nostril (NLA). Unfortunately, both the Valence Hypothesis and the Right Hemisphere Hypothesis make the same predictions for the negative smells.

Results revealed a significant interaction effect for Odor Valence by Nostril by Direction F (1,9)= 6.00, p<.05.The direction in which the neonates turned their heads was affected by which nostril was stimulated and the valence of the odorant (as seen in Table 11). Post hoc analyses, Tukey HSD, revealed the following significant results. Significant effects occurred only for the **positive** smells. When positive smells were directed to the left nostril, more towards head movements occurred (PLT mean= .90) than when positive smells were directed to the right nostril (PRT mean= .50). Positive smells directed to the left nostril elicited more towards head movements (PLT mean= .90) than away head movements (PLA mean=.30), as depicted in Figure 8. Although there were no significant differences for negative smells when they were directed to the right nostril slightly more away head turns occurred (NRA mean= .50) than when directed to the left nostril (NLA mean=.30).

Table 10. Predictions Made by the Valence and Right Hemisphere Hypothesis.

	Right Hypothesis	Valence Hypothesis
Positive	PRT>PLT	PLT>PRT*
	PRT>PRA	PLT>PLA*
Negative	NRA>NLA	NRA>NLA
	NRA>NRT	NRA>NRT

* Findings from Study 2

Table 11. Mean Number of Head Movements Towards and Away from the Odorants.

Condition	Mean*	Standard Deviation
PRT	.50	.71
PLT	.90	.99
PRA	.70	1.1
PLA	.30	.67
NRT	.60	.84
NLT	.40	.52
NRA	.50	.71
NLA	.30	.68

* Means range from 0 to 4.

Figure 8. Mean Number of Towards and Away Head Movements (±1 SE) for each Type of Stimulus

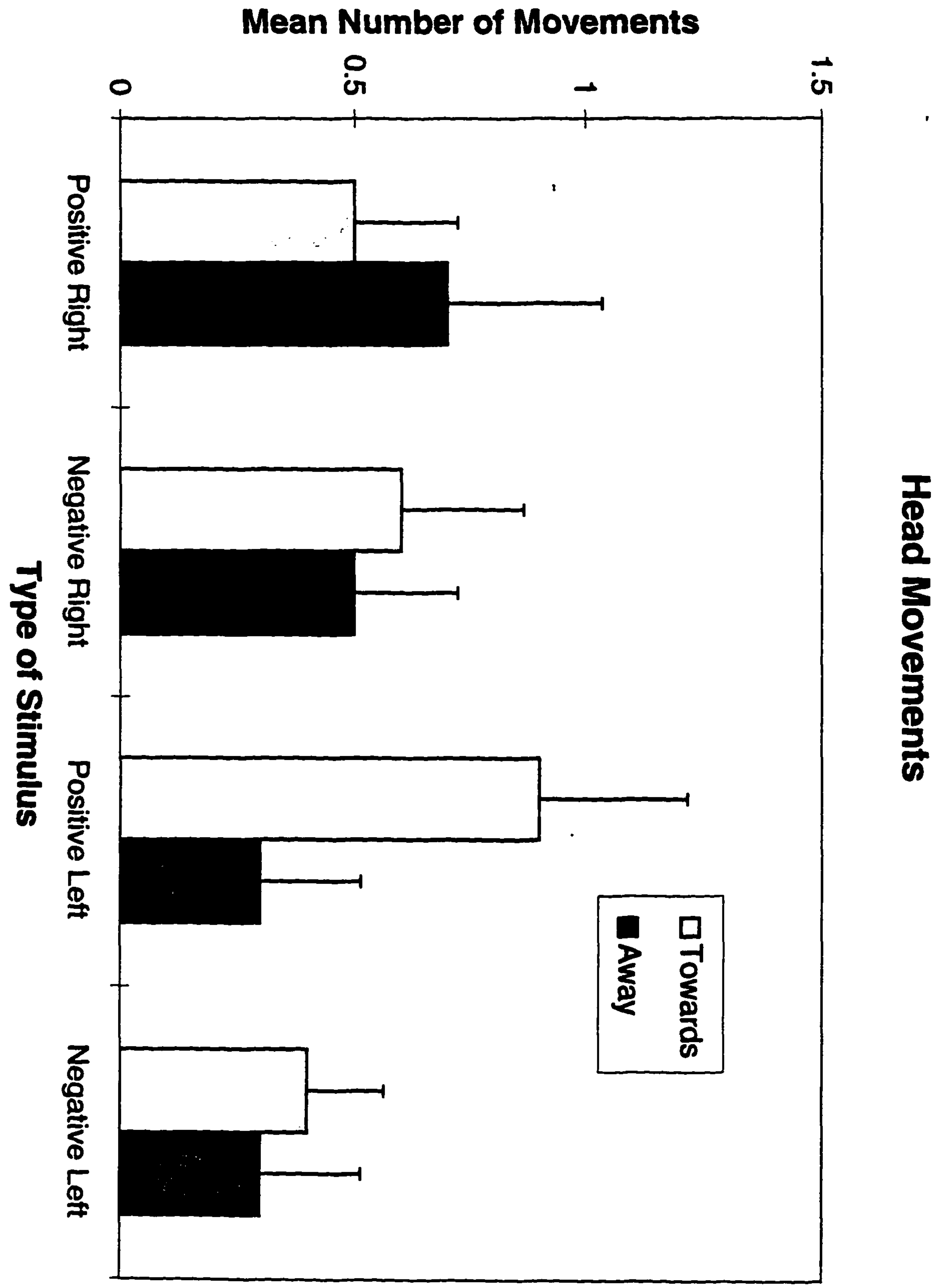
Head Movements
Mean Number of Movements
0
0.5
1
1.5
Towards
Away
Positive Right
Negative Right
Positive Left
Negative Left
Type of Stimulus

Figure 8

Discussion

The findings from Study 2 replicate the findings from Study 1 that newborns can differentiate between a smell verses a control. More important, by placing newborns' heads in a midline position at each trial's start, this study was able to evaluate the hypotheses raised in the introduction. Results revealed that neonates made significantly more head turns to the positive odors presented at their left nostril than to their right nostril. These findings will be discussed in terms of the various hypotheses raised regarding hemispheric specialization of emotions.

Unfortunately, some of the proposed hypotheses have some degree of overlapping predictions so that, in some cases, it is impossible to choose among them.

The Right Hemisphere Hypothesis

The Right Hemisphere Hypothesis states that emotions are a function of the right hemisphere. The majority of studies support this interpretation; though as mentioned, most of the past evidence has been obtained with adults. Support in this study would have meant that when the smells, independent of valence, were directed to the right nostril more head turns would have occurred than when the smells were directed to the left nostril. To the extent that the right nostril presentation represents right hemisphere activation and left nostril presentation results in left hemisphere activation the present studies rule this hypothesis out. However, had the odors possessed a trigeminal element interpretation would be ambiguous because while olfactory projections are ipsilateral trigeminal innervation is contralateral. In that, odorants were carefully screened for any trigeminal components, utilizing a technique employed by Madigan, Ehrlichman and Borod (1994) it seems unlikely that they resulted in trigeminal activation. Some researchers suggest (Silver, 1987; Silver & Maruniak, 1981) that all odorants, if of a high enough intensity, possess the potential for stimulating the trigeminal nerve. In the current studies, all odors were of a low enough intensity for this not to be likely. It therefore seems exceedingly unlikely that trigeminal stimulation was involved so that the Right Hemisphere Hypothesis would be disconfirmed at least as far as neonates were concerned.

Valence Hypothesis

The Valence Hypothesis states that the left hemisphere specializes in positive emotions and the right hemisphere specializes in negative emotions. The findings from the current studies provide partial support for the Valence Hypothesis in that presentation of positive olfactants to the left hemisphere resulted in more towards turning than did presentation of the same olfactants to the right hemisphere. For negative emotions, no significant difference across the hemispheres was found. It is of note however, that the results for negative emotions are also in the direction predicted by this hypothesis. Slightly more away head turns (NRA mean=.50) occurred when the odors were directed to the right hemisphere than when directed to the left hemisphere (NLA mean=.30).

Approach-Withdrawal Hypothesis

The Approach-Withdrawal (A/W) Hypothesis advocates a bioevolutionary perspective, advancing the idea that emotions are discriminated according to their positive or negative consequences. The basis of this hedonic polarity is an approach-withdrawal distinction (Bowlby, 1972; Fox & Davidson, 1986; Izard, 1977; Kinsbourne, 1978). For the following discussion approach-withdrawal is described in a manner consistent with Schneirla's conceptualization. Approach withdrawal behaviors were seen as directional responses to spatially distributed stimuli with no implication of any type of awareness on the part of the responding organism.

The mechanisms underlying the approach-withdrawal distinction are presently being discussed. An Intensity/Arousal Theory (Schneirla, 1977) and a Motoric Theory (Fox & Davidson, 1986) have been postulated.

A) Intensity/ Arousal Theory

Schneirla's (1959, 1977) A/W theory states that early in development directional responses are intimately tied to the intensity of stimulation. Thus, approach or A-type consummatory behaviors are initiated by weak stimuli and withdrawal or W-type defense behaviors are initiated by intense stimuli. Emotional reactions are decoded dichotomously as a "go/ no go decision". Infants are bombarded with stimuli which require responses; either they attend to it or ignore it. If a stimulus does elicit attention, the next step is to approach or withdraw from it. According to Schneirla, A-W adjustments are made in conjunction with changes that occur as a result of the intensity of the stimulus. High intensity stimuli arouse the sympathetic nervous system causing the organism to retract or withdraw thereby increasing its distance from the aversive situation. In contrast, low or moderate stimuli engage the parasympathetic nervous system resulting in approach behaviors whereby the neonate comes nearer to the source of stimulation.

If the Arousal/Intensity Theory were to be supported, since all the odorants were of a low intensity (see above), the neonates should have approached all odorants equally, independent of their valence or which hemisphere they were stimulating. In fact, critics may argue that it is possible, by using odorants of low intensities, to have inadvertently introduced a bias towards approach behaviors as predicted by Schneirla.

Examining Figure 2, a number of conclusions can be drawn. First, the only significant finding was that approach behaviors occurred only when the positive odors went to the left hemisphere. It is true that slightly more approach behaviors (head turns toward) occurred for the negative smells, independent of hemisphere, but the results were non-significant. Finally, when the positive smells went to the right hemisphere, more head turns away occurred, though also non-significant. Schneirla's Arousal/Intensity Theory could account for some of the above findings and thus must be entertained. Schneirla's theory addressed effective intensity and predicted that young organisms would tend to approach weak sources of stimulation and withdraw from more intense sources. His theory also stated that approach behaviors developmentally precede withdrawal behaviors - a finding that was supported by Study 2. Schneirla's theory, however, does not address issues of lateralization, an added dimension in these studies. The results from the present studies indicated that the interaction of an odorant's valence (positive), and the hemisphere that it was stimulating (left), was the significant factor.

B) Motor Theory

Occupying a central role in affective development, Fox and Davidson (1986) see approach-withdrawal behaviors, at first, as relatively independent unidimensional systems driven by a set of innate opposing motor programs. For these researchers, A-type behaviors involve such things as: food-getting, shelter-gathering, and mating. W-type behaviors involve defensive actions such as: spitting out, expulsive behaviors, and head turning away.

Approach behaviors for Izard (1977) are important sequelae for the activation of interest, while withdrawal behaviors are important determinants for the activation of disgust. Considered the most prevalent of all the emotions, interest is conceptualized as a primary discrete emotion that functions in focusing and maintaining attention. Interest engages perceptual and cognitive processes (Izard, 1977); thus, it might make sense for its emergence to precede some of the other emotions.

In the present studies, if the Motor Theory were to be supported, the neonates would have turned their heads toward the positive stimuli and away from the negative stimuli. Findings revealed that significantly more toward head movements were made to the positive odorants, especially when they were directed to the left hemisphere. Though not significant, the findings revealed that neonates approached negative smells slightly more than they withdrew from them, as seen in Figure 2. Thus, the Motor Theory is partially supported by these findings.

As demonstrated the results from the present studies do not totally fit any of the existing explanations. Though speculative a new theory is added to the arena.

Approach to the Left Precedes Retreat to the Right

This proposal borrows concepts from Schneirla, Zajonc, Turkewitz and LeDoux. Advanced: that approach behaviors (emotional expressions) surface before withdrawal behaviors and are a function of the left hemisphere.

Because of extended dependence on parental care, altricial nature, selective pressures may have advanced development of approach behaviors over withdrawal behaviors. Both behaviors are adaptive, furthering neonates' chances for survival and aid in maintaining communication. Approach behaviors would emerge first because of their prime importance in seeking nutrition for survival. Subsequently, with mobility, infants face greater likelihood of encountering potentially dangerous situations which necessitate the genesis of withdrawal behaviors. An alternative explanation for earlier emergence of approach behaviors may be found in the prenatal literature.

As in other sensory modalities, (i.e., auditory see Decasper & Fifer, 1980), the possibility exists that prenatal exposure with odors can establish post-natal preferences (Hepper, 1988; Pedersen & Blass, 1982).

In the present studies, food-related odors were used with the assumption was that these were novel odors to the infants. While this may be true postnatally, it may not have been the case prenatally. Since the olfactory system is functional prenatally (12th gestational week), the possibility exists that the fetuses were exposed to these odors in the amniotic fluid. During pregnancy mothers were apt to eat foods containing positive odorants, vanilla and almond, as opposed to ingesting sour milk or rotten eggs. Thus, the fetuses may have had in utero experiences with these positive stimuli via the maternal diet. This familiarity dimension may be the basis of their approach behaviors.

Speculating further as to why approach behaviors might precede withdrawal behaviors requires a reexamination of important, albeit, seasoned literature. Schneirla (1959) proposed that A-type behaviors are associated with the parasympathetic nervous system whose development predates W-type behaviors associated with the sympathetic system. The parasympathetic nervous system maintains homeostatic functions and is said to be energy conserving and low intensity. Positive emotions require minimal motoric activity, no instrumental response or energy investiture on the part of the responding organism and thus are connected to the parasympathetic system. In contrast, the sympathetic nervous system is energy depleting, reactive and of high intensity. Negative emotions place substantial demands on their recipient thus becoming associated with the "fight or flight" branch of the autonomic nervous system.

The idea that positive emotions are tied to the parasympathetic system and negative emotions to the sympathetic is not a new one. Bovard (1962) believed that positive emotions activated structures in the frontal cortex and lateral hypothalamus and were accompanied peripherally by shifts in the parasympathetic system and negative emotions were accompanied by shifts in the sympathetic system. Schneirla concurred and introduced the idea that the parasympathetic nervous system (positive emotions) developed prior to the sympathetic system (negative emotions). This assumption is supported by the finding that regulation of positive affect is achieved earlier than regulation of negative affect (Matias & Cohn, 1993).

Though controversial, several researchers have proposed a left-to-right gradient in the early maturation of the hemispheres (Bever, 1978; Corballis & Morgan, 1978; Corballis, 1991). Supporting the above interpretation, Hepper et al., (1991) observed via ultrasound recordings that, in terms of hand preference, fetuses from 15 weeks to term displayed a strong bias for thumb sucking of the right hand (motor system contralaterally innervated). Again, this suggests an earlier maturation of the left hemisphere. This hand preference was maintained throughout pregnancy and was unrelated to fetal position in utero but, correlated with head position preference in the supine neonate. When infants were tested shortly after birth, they exhibited a preference to turn their heads to the same side they thumb sucked, the right. Hepper et al's, study (1991) served to further confirm the postural asymmetry findings of Turkewitz, Birch, Moreau, Levy and Cornwell (1966) and Michel (1981) who noted more rightward head movements (implicating the left hemisphere) with newborns. Turkewitz (1977) submitted that infants' head-right postures may serve as the basis for the development of lateral differences in the responsiveness to various sensory stimulation.

Pursuing this line of reasoning, since neonates lie more on their right sides, they may be preferentially breathing through their left nostrils, activating their left hemispheres. Behaviorally, neonates exhibit more positive emotions possibly generated by a more active parasympathetic nervous system.

Adding another element to the evolution and function of emotions, Zajonc's Facial Efference Theory (Zajonc et al., 1989) proposes that parasympathetic excitation induces nasal vasodilation in the mucosal vasculature. Based upon the present studies it is hypothesized that this vasodilation occurs exclusively in neonates' left nostrils. Expansion of the mucosal vasculature produces a loss of heat convectively as the cooled blood travels to the cavernous sinus via the internal jugular system with the hypothalamus the final destination. Zajonc contended that at both behavioral and physiological levels a close link between thermoregulation and emotions. Cooling of the brain is felt as pleasurable. In contrast, sympathetic excitation induces mucosal vasoconstriction as warmed blood travels the same route and retards heat dissipation from the hypothalamus. This rise in temperature is experienced as unpleasant. Thus, the temperature of the brain is affected by nasal vasomotor tone (Blumberg & Moltz, 1988).

The locus of emotional experience does not solely rest with the hypothalamus. LeDoux (1989) has provided anatomical evidence for the importance of the amygdala and its connections to the autonomic nervous system. In addition, major pathways exist from the nose to the amygdala which is functional at birth.

Mediating Variable

1) The Nasal Cycle

A potential variable that may have had an effect on the reactions of the newborns is nostril dominance.

This was not determined at the experiments' onset. Also, since experiments sometimes lasted as long as an hour, the nasal cycle could have shifted. The significance of this was addressed in the paper and provided part of the rationale for Study 2. The new theory advanced suggests that, as a consequence of lying on the right side, neonates preferentially breathe through their left nostril. This assumption warrants empirical investigation since nostril dominance was not determined due to lack of appropriate instruments. However, it has been found via electron microscopy that the general neonatal nasal vascular architecture is similar to that described for adults (Skladzien, Litwin, Nowogrodzka-Zagorska & Miodonski, 1995).

The assumption that neonates preferentially use their left nostrils is not unusual since, in adults, a right nostril dominance has been demonstrated by a number of independent researchers (Zatorre & Jones-Gotman, 1990; Yougentob, Kurtz, Leopold, Mozell, & Horung, 1982). It remains to be determined however, if this left-nostril dominance (due to mucosal vasodilation) holds true for infants.

Future Study:

A future study on hand movements is offered to explore whether the parasympathetic system develops earlier than the sympathetic.

In Study 1 hand movements were grouped as one category, not separated in terms of right or left gestures. Since hand movements are contralaterally innervated it would be interesting to first determine if more right (activating left hemisphere) than left movements occur. In addition, the type of hand movement made i.e., extension verses flexion could be noted. Finger extension is wired to the parasympathetic nervous system and finger flexion is wired to the sympathetic nervous system. Using finger extension verses flexion as response measures, the validity of my hypothesis could be tested (see Tukewitz et al., 1966). The prediction is that more finger extension occurs when the neonate approaches an olfactory stimulus presented to their left hemisphere.

Summary-

Acknowledging that the hypothesis advanced is controversial, perhaps even against mainstream positions, adds more challenges to the literature on laterality of emotions and the ontogeny of hemispheric specialization for emotions. The implications for this finding that emotional expressions and possibly experiences (positive and negative) do not develop synchronously clearly necessitate a closer examination. Further experimentation observing infants behaviorally in coordination with physiological studies is warranted.

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